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ABSTRACT

The Paris Faculty of Science is developing programs in computer-assisted instruction (CAI). Their first goal is to develop "questionnaires" (instructional sequences) administered by teletype machines which check on a student's knowledge in an area and draw his attention to basic concepts, definitions, and theorems in that area. Using an IBM 360/30 computer, the research team has modified the basic hardware system and developed appropriate computer languages and software systems, which are described here. With this equipment, the teaching team has developed questionnaires for CAI in mathematics, physics, biology, and English (linguistics) for college undergraduates. The scope of these programs and steps in producing them are discussed. Revision of these programs is currently taking place. (JK)

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centre for educational research and innovation

COMPUTER-ASSISTED INSTRUCTION

THE EXPERIMENT OF THE FACULTY OF SCIENCE IN PARIS

technical report

EM 008 934

OECD ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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ORGANISATION FOR ECONOMIC
CO-OPERATION AND DEVELOPMENT

Centre for Educational Research
and Innovation

CERI/CT/70.60

Paris, 31 March, 1971

Or. fr.

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CONFERENCE ON THE USE OF COMPUTERS IN HIGHER EDUCATION

held in Paris from 19th-21st March, 1970

(Joint Project CERI XI)

Computer assisted instruction

by Professor LE CORRE and Professor R. JACOUD and
their research team from the
"Computer for Students" Laboratory
of the Paris Faculty of Science (France)

79.524

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INTRODUCTION

The following document, prepared by the "Computer for Students" team of the Paris Faculty of Science Directors (Professor Y. Le Corre and R. Jacoud) from a more extensive report, describes the various aspects of the computer-assisted instruction experiment conducted in this Laboratory. The experiment forms part of the Joint Project on "The Use of Computers in Higher Education" undertaken by the OECD Centre for Educational Research and Innovation (CERI). Other studies will be published by CERI, each describing the various experiments now proceeding under this Joint Project, in which the following laboratories and university centres, as well as the team mentioned above, are concerned:

United Kingdom:	University of Cambridge, Department of Applied Mathematics and Theoretical Physics, Director: Prof. G.K. Batchelor.
Belgium:	University of Louvain, General Physics Laboratory, Director: Prof. A. Jones.
Netherlands:	University of Leiden, Department of Education, Director: Prof. L. de Klerk.
Japan:	University of Osaka, Department of Education, Director: Prof. S. Tanaka.

The objectives of this Joint Project are numerous and have been described in detail in several documents already issued by CERI. It seems, however, advisable to recall the main points:

1. Preparation of recommendations for a policy on computer utilisation in education

Experiments are too often abortive or linger on without producing interesting results. The reasons for these relative failures vary considerably according to the case, but one thing is nevertheless certain: the novelty of this teaching "tool" on the one hand, its obvious and often fascinating possibilities on the other, and the need to include it in more comprehensive thinking about teaching and learning processes, should lead to its utilisation being considered on the basis of development-oriented educational research. Responsibility for such research will ultimately devolve on the educationalists and the national authorities. That is why it is important to help them to define their options and make their decisions - this is indeed one of CERI's major roles - by providing them with the best possible information.

2. Consideration of a number of questions specific to the use of computers as teaching instruments

For the teacher as well as for the student, the dialogue with a computer is in fact the simulation of an extremely complex teaching situation. Computer-assisted instruction constitutes a reduction of this. Numerous questions arise - among them the following:

(i) How should the educational content be organised? Are there one or more "possible approaches", and in the latter case, are some of them optimal?

(ii) How should the course "input" to the computer be arranged? In other words, a teacher cannot be expected to be a highly skilled computer scientist but, conversely, the "language" which he is to use to communicate with the computer should be sufficiently rich and flexible to enable him to express the subtleties and various aspects of the teaching process.

(iii) How should the student's behaviour be taken into account? For instance, how should his replies to the computer's questions be handled and analysed? To stick to "multiple-choice" systems soon becomes an over-facile solution.

(iv) Is there an ideal "configuration" for computer-assisted instruction? What are the advantages and disadvantages of the various types of terminals?

(v) How should the computer's role as a teaching instrument be "assessed", from both an educational and an "economic" viewpoint? In other words, is computer-assisted instruction profitable?

(vi) How should the computer be integrated into the educational process? The problems involved are not only technical or pedagogic but also sociological.

The following document does not claim to give a definitive answer to all these questions but - and this is to its credit - it describes in detail an experiment which, although still unfinished, nevertheless forms an instrument of reference.

I. PROBLEMS THAT AROSE AND SOLUTIONS FOUND

1. PROBLEMS THAT AROSE

A. Teaching problems

The massive influx of students for the Certificat d'Etudes Supérieures d'Electricité (undergraduate electricity course) led us, by 1965, to wonder about modernising our teaching methods. At that time, we were responsible for providing high quality instruction for 2,000 students, using a faculty of 17 (3 full professors, 14 junior faculty).

The teaching programme was divided into large lecture courses, small discussion groups (of 30 to 35 students), and oral questioning sessions. Although the arrangement was considered satisfactory as far as the small discussion groups were concerned, the oral testing system by no means met with expectations, that is to say, it did not offer weekly conversations between student and teacher, during which the acquired knowledge and understanding are explored, action then taken to remedy weaknesses, and if need be the student sent to review the course work.

Of all the possible levels to take remedial action at lecture courses, discussion groups or testing sessions, we chose the testing session. This choice was dictated by the following observations.

When a student gives a report, any error or misunderstanding generally shows up well after the error in reasoning has been committed. The student should therefore be corrected before the error appears. The job of finding the exact point at which the student began to go wrong can only be accomplished by a staff which is highly qualified and thoroughly experienced in teaching, in short, the staff which is already assigned elsewhere (to cover the discussion groups) and is irreplaceable. In these circumstances, the oral questioning sessions were handled by graduate students or by students from special élite schools (Grandes Ecoles). Though they were knowledgeable enough, they were woefully lacking in teaching experience, so that the testing sessions, at that time, turned into mere monologues, and they had no purpose other than to provide grades (whose value was left in doubt).

Hence we thought that an automated system would allow us to solve the problem of checking on the students' knowledge. We stated the problem in this manner:

- Imagine a communications system which would allow the student to know accurately, regularly and without wasting time, how his knowledge stood, and which would draw his attention particularly to basic concepts, fundamental definitions and important theorems.

Starting with this definition, two paths are open. Either one confines oneself to a mere diagnosis (which means a simple examination system), or else one tries to step in at the very moment a mistake is made in order to correct, re-explain, and provide extra information (which means what we have called self-examination).

In view of the possibilities of the tool (a computer) which we were hoping to get, we quite naturally agreed upon the latter path. This choice implies answers to three commanding requirements:

- allowing the broadest possible answers,
- permitting the fullest possible branching,
- making it possible to perform computations during the examination.

Once this framework was outlined, it was necessary to think about using such a system at two levels:

- The immediate practical level:
  - impact on the contents of the lecture course
  - impact on the students themselves
- The basic research level:
  - to begin with, by developing the study of errors, correlations between errors, etc...

Making use of this system meant developing a means of recording statistical data such as

- the headway made by the student
- the number of correct answers
- the number of wrong answers
- the time taken to answer
- unexpected answers
- answers students give to questions about their reactions (how sure they are of an answer, for example).

B. Technical problems

The technical problems that arose as we carried out the experiment we had planned could be tackled from various angles, but it was important for us to solve them in a way that did not hinder the project's development. Every new teaching problem had to be expressed and solved within the chosen technical environment.

Furthermore, in that we were among the first groups(1) to attempt to raise this kind of problem, it was not possible for us to make use of prior experiments and results obtained under similar conditions.

Although we had set modest goals, they seemed too ambitious for us to be able to use electromechanical systems such as "teaching machines". A certain kind of programming (linear or divided) must be decided on once and for all before such a system can be adopted, so that this equipment creates immense difficulties if it has adjusted to meet radical changes in procedure, and it cannot be used to analyse free-lance answers.

Apart from the practical problems involved in setting up and financing a system based on a computer, it offers features which best match the problems which come up in teaching:

- the possibility of storing a large volume of data on rapid, random access surfaces (diskpacks and drums)(2)
- using the computer on a time-sharing basis makes it possible for a large number of users to be connected to one central facility.
- storing information in real time, so that it can be used during sessions (access to information about all the students) or afterwards (using standard computer facilities).
- the possibility of using a wide variety of terminals, such as typewriters, viewing screens, sound readers on magnetic tapes.

These features, along with the fact that a computer offers much greater theoretical flexibility than a "teaching machine" does, led us to make the choice we did.

Once the choice was made, however, all the technical problems connected to implementing plans and using the computer remained, namely, writing the necessary software programmes.

Some basic software-assembler, compiler, supervisor - can be supplied by the constructor, but this component is rarely adapted to any particular application, especially if it is not a common one. Thus, it is necessary to go about defining and working out a system and programmes specially designed for the experiment at hand. Thus, we had to choose between two alternative solutions:

- modify existing software, with all the "risks" that using a "rebuilt" system carries - the most economic but the least trustworthy option,
- write a new, suitable system.

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(1) Outside of experiments done in the USA, but having a philosophic basis different from ours (teaching done by computers, teaching directed by computers or else various simulations by computers).

(2) We decided against using tapes because their access is not rapid or simultaneous.

Finally, for the problem of choosing a programming language, there are also two possible approaches:

- a machine language (assembler),
- one of the developed languages (Fortran, Algol, Lisp).

The choice depends to a great extent on the system which the constructor supplies and on the central storage capacity available.

If only limited performance is required, a developed language can be used. In this way the time needed to write and debug the programmes is cut down.

In the light of these considerations, the job of programming can be classified in three categories:

- the operating programme for the terminals - it depends a lot on the type of terminal chosen and on whether or not there is a time-sharing monitor supplied by the constructor.
- the programme for processing and recording data collected - statistical breakdowns, learning models, etc...
- the programme for organising the dialogue with the student - specific languages for the course-writer, or creating a file directly by using a system which already exists; analysing student answers in as much as the dialogue should be as natural as possible. (Ultimately this problem is insoluble if a truly free dialogue is sought. Since semantics cannot be handled by the computer, one has to decide to what extent it can be broken down into problems of syntax).

At any rate, when organising all these programmes, a modular structure is vital if additions or modifications are to be possible without upsetting most of the work already accomplished.

2. SOLUTIONS FOUND

A. The research team

One of the basic problems was to create a smooth-running team made up of both the people brought in to solve technical problems and those who would devote themselves more particularly to working out the questionnaires.

The desirable compromise between instructional needs and technological limitations requires thorough-going communication between the system's users (teachers) and the computer experts. If this dialogue is to be fruitful, at least part of the software group must have a solid scientific education in the field involved (in our case, physics). For this reason, we started off by setting up two groups:

The computer group, which was made up of two faculty members teaching the undergraduate electricity course who knew about computers and electronics, plus one programme analyst. The purpose of this group was to look into the issues raised by the teachers and to come up with solutions which would prove satisfactory for the users and compatible with the system.

The instructional group, which was composed of 6 full-time[1] faculty members, aided by other teachers who were paid extra for their overtime work. This group was responsible for drawing up the questionnaires, on which the experiment rested.

The staffs and size of these groups fluctuated from time to time, either because people were reassigned to other departmental jobs or because they left to carry on other activities.

From the outset, we encountered various problems in psychology which led us to hire a psychologist, who was responsible for studying how and what motivated students to learn.

At the present time, the University Chancellor and the Physics Committee have agreed to let the Student Computer laboratory team be made up of faculty members, most of whose teaching programmes are connected to this experiment, and some of whom are conducting research in this area.

This team was joined by a group of students chosen amongst those who had been involved in the experiment. The student groups, working under faculty supervision, take part in formulating, writing and testing the questionnaires.

In addition, another group of 6 students took on the job of typing up and recording the questionnaires.

The original team of faculty members was made up entirely of physicists because the first goal set up was writing questionnaires for the old undergraduate major course in electricity. Very quickly, however, some of our colleagues who were interested in the experiment resolved to use the existing system to find out how far it could be applied to their own fields. As a result, at the present time, there are two teams working in the laboratory, one of biologists, the other of linguists studying English. Although these two teams are not connected as far as their teaching is concerned, they contribute to working out new structures, and they take part in overall discussions seeking ways to make use of computers in teaching.

A glance back over the work which has been accomplished since this experiment began and which is summarised in its up-to-date state in this report allows one to draw a few conclusions about how to form teams to set up and make use of a computer and its component equipment, in the context of a traditional teaching programme.

In order for such an experiment to be implemented sensibly, a minimum staff(2) must be brought together, for otherwise it would be

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(1) This means that their entire teaching programme was devoted to the Student Computer (O.P.E.) laboratory.

(2) Note that we are considering here a situation in which no prior set up exists which could be used for teaching purposes. This influences the size of the staff needed, especially the number and the training of the computer experts required.

foolhardy to expect this kind of undertaking to be successful. Our personal observations make us think that the optimum number of staff members is about twenty, divided into 3 groups.

- A group of computer experts of from 5 to 7 members, of whom 2 or 3 should be analysts and 2 or 3 study programmers.
- A group of faculty members, about 10 in number, including 2 or 3 who should bridge the gap between the teaching and computer staffs, or between the teachers and psychologists.
- A group of psychologists, 2 or 3 in number, at the level of advanced graduate students, who are able to follow the subject matter being studied, since their work must be part of the team study of cognitive processes.

It would be desirable to have one or two experienced researchers to co-ordinate the various activities of such a team, men with broad backgrounds, having not only a solid education in science but also basic training in psychology and computer technology.

B. Solutions in teaching

Among the many possible solutions found for various problems which were anticipated (cf. 1.1.A) we decided to devote ourselves to devising a system for self-examination.

This choice implies the following prerequisite conditions:

1st - A scientific subject must be chosen, in this case, Physics.

2nd - A questionnaire must be worked out which has specific purposes:

- to check up on concepts
- to supply extra information if need be
- to make a synthesis of various concepts
- to provide practice in applying the material

3rd - The questionnaires must lead to systematic criticism of instruction

- the necessity of providing a chance for unstructured answers
- the necessity of being able to follow the thought patterns of each student
- the necessity of recording unexpected answers
- the necessity of allowing students to make comments, for example, about how sure they are of an answer or how difficult they find the question.

Hence we ended up by defining a normal sequence which includes the questions designed to take care of the basic concepts in the part of the course involved, and a drifting sequence containing extra information designed to enable the student having difficulty to grasp some of the concepts escaping him.

Therefore, we started off by choosing the structure which corresponds to the following diagram, in which each question and its related answer block is represented by circles, while the various branching possible after a given answer are represented by arrows.

Of course, any of the possible jumping patterns can be used within a single answer-block, since the block allows for various processing alternatives depending on the various types of answers which have been planned for.

Later on in this report, in the chapter on applying the questionnaires, examples are given to show how this diagram was put into practice and what solutions were found to satisfy the various prerequisite conditions enumerated above.

C. Technical solutions

After studying the models on the market, we decided to get an IBM 360/30 system, whose exact layout is given in Figure 1.

At the time we were planning the experiment, our budget for the project and the instructional goals we had set up left us practically no freedom of choice.

It was understood, moreover, that the project would get under way with a minimum set up, but the development phase could be undertaken without extending the central store and increasing the number of diskpack units. With this in mind, we added another diskpack 2311 to our system.

At the present time, the processor's central memory contains 16K eight bit bytes, but we are hoping that we will soon move up to the 64K because the system is not trustworthy enough. As a matter of fact, in order to save on space, we have been forced to cut back on certain "hardware" inspection sub-programmes and to simplify our basic system. This may be a relatively minor aspect of the beginning phase, where the main point is to check that the processing algorithms are relevant, but in the operations phase it acquires vital importance and causes considerable difficulty.

The diskpack 2311, connected to its control unit 2841, has a capacity of 7.5×10^6 characters. It is used to back up the system and application programmes, as well as the card files used for examinations (questionnaire files, student files) or for the system (binary programme files, macro-instruction files, etc.).

Access-time is relatively short (75 ms, on the average) and recordings are organised in the following simple manner:

We have 200 cylindrical drums available, each of which has 10 tracks. The desired number of recordings can be created on each track, within the maximum capacity of 3600 eight bit bytes for each track, and provided each recording is separated from the following one by a large "between-recording" break space which cuts down on the "useful" capacity of the track.

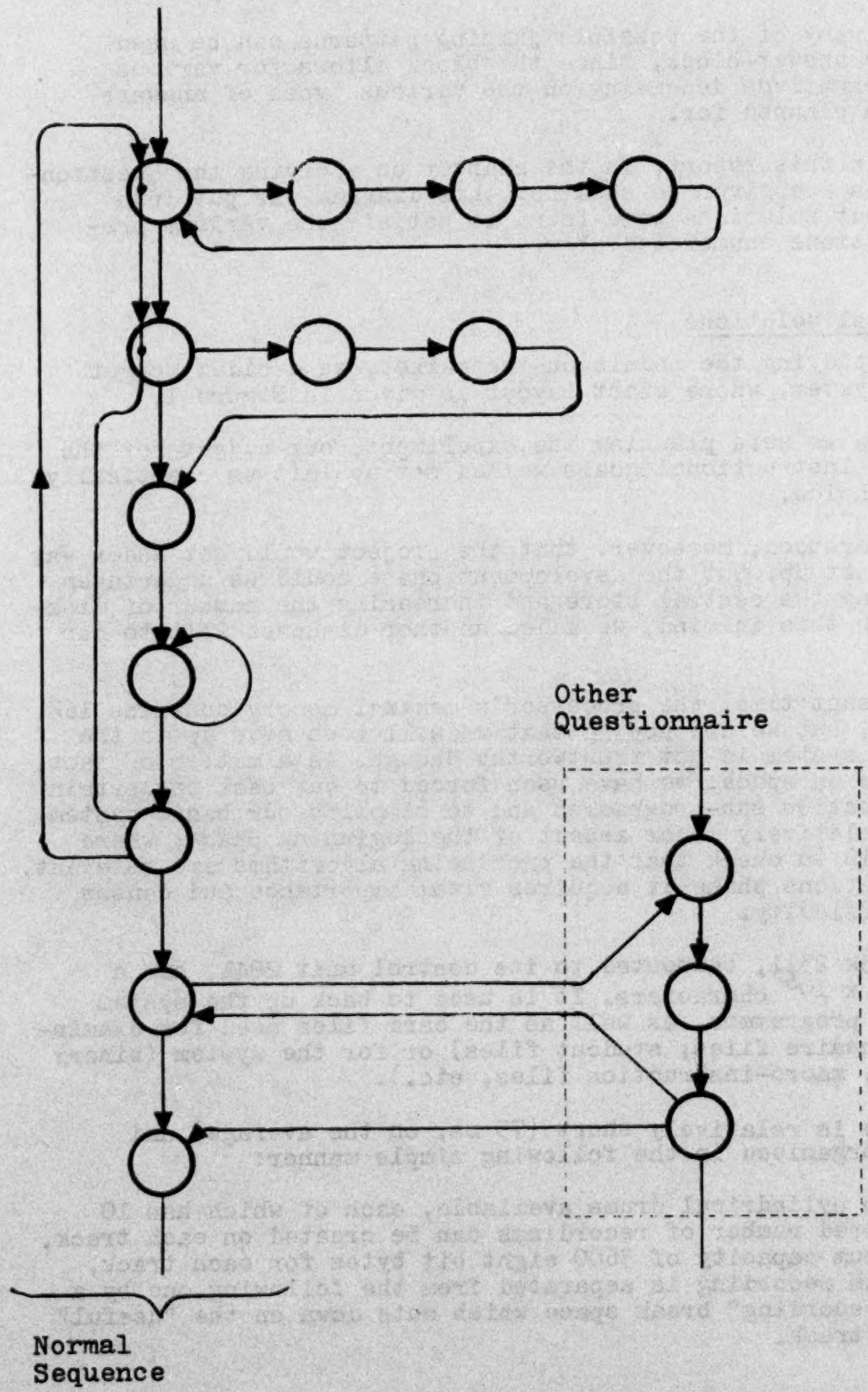
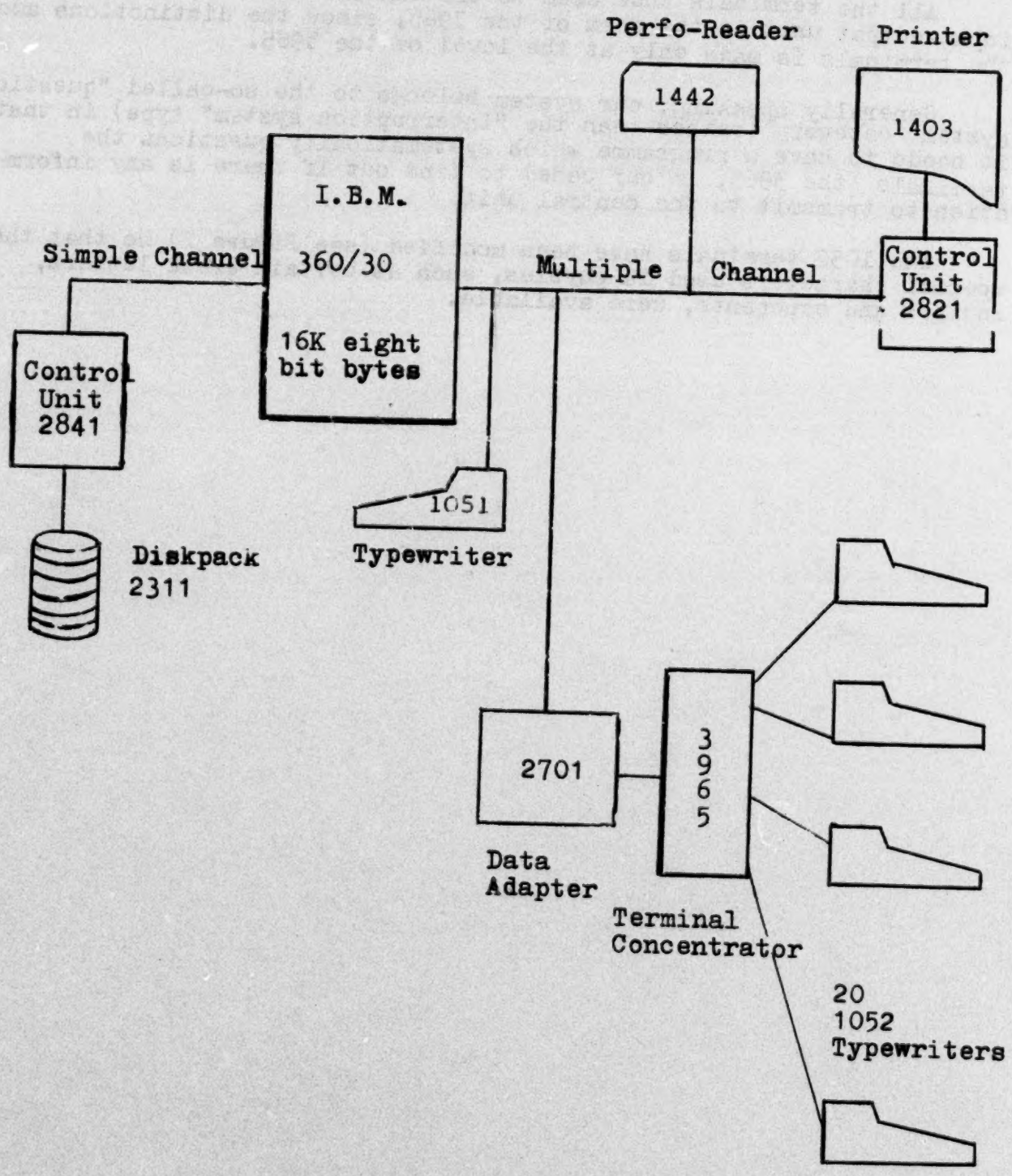

Other
Questionnaire
Normal
Sequence

FIGURE 1

MACHINE SETUP

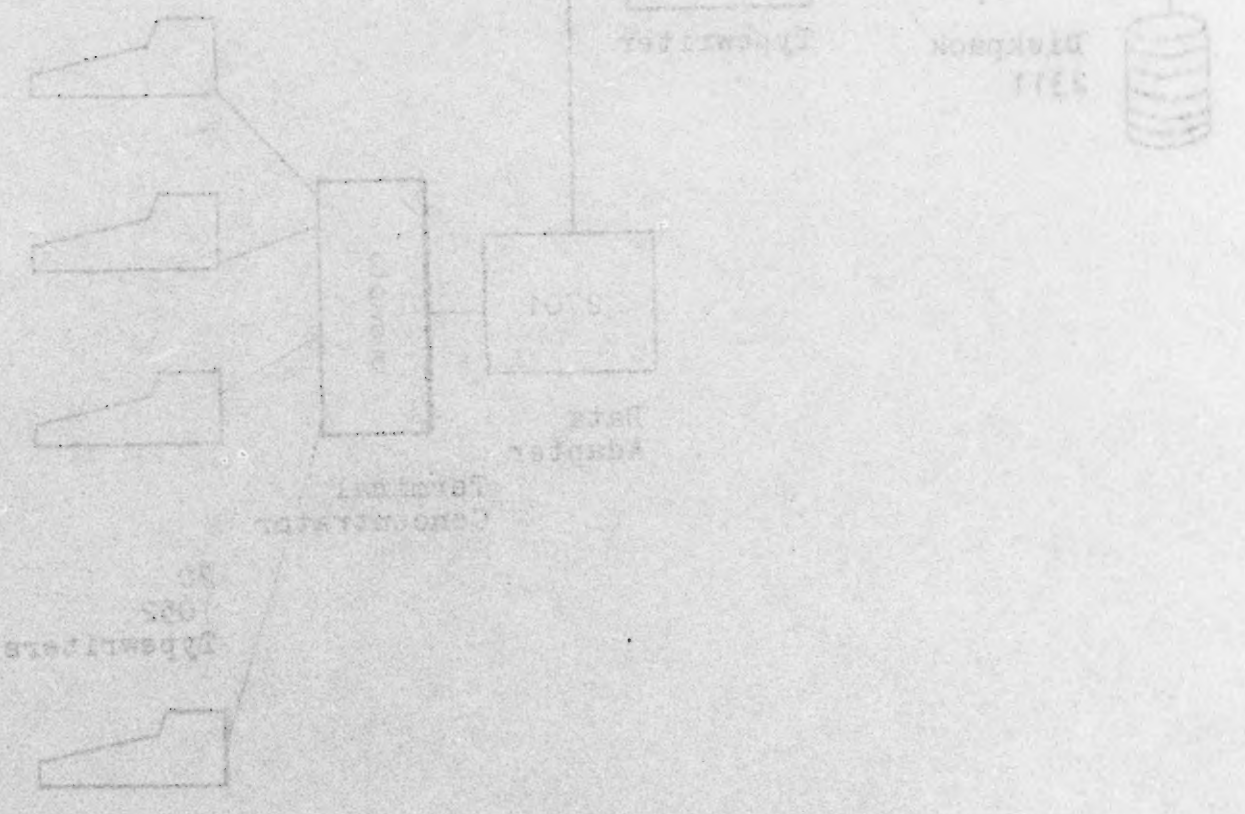


The 2701-3965 system, which is connected to the multiple channel, handles the terminals (model 1052 typewriters). Transmission between the central unit and the 2701 is done in parallel (8 bits), while that from the 2701 to the 3965 is done in series by coaxial cable. The 3965 unit is a terminal concentrator which for each terminal has a buffer store with 59 characters. This buffer, built with two delay lines, has the same input-output for any given terminal. This set up is a source of trouble between information coming from the central unit and that coming from a terminal (user). The system is built to give the user priority.

All the terminals thus seem to the central unit to be a single input-output unit in the form of the 3965, since the distinctions among the terminals is made only at the level of the 3965.

Generally speaking, our system belongs to the so-called "question system" category (rather than the "interruption system" type) in that it needs to have a programme which systematically questions the terminals (the 3965, in our case) to find out if there is any information to transmit to the central unit.

The 1052 terminals have been modified (see Figure 2) so that the special characters used in physics, such as certain Greek letters, indices and exponents, were available.



ARRANGEMENT OF THE "ELECTRICITY COURSE" KEYBOARD

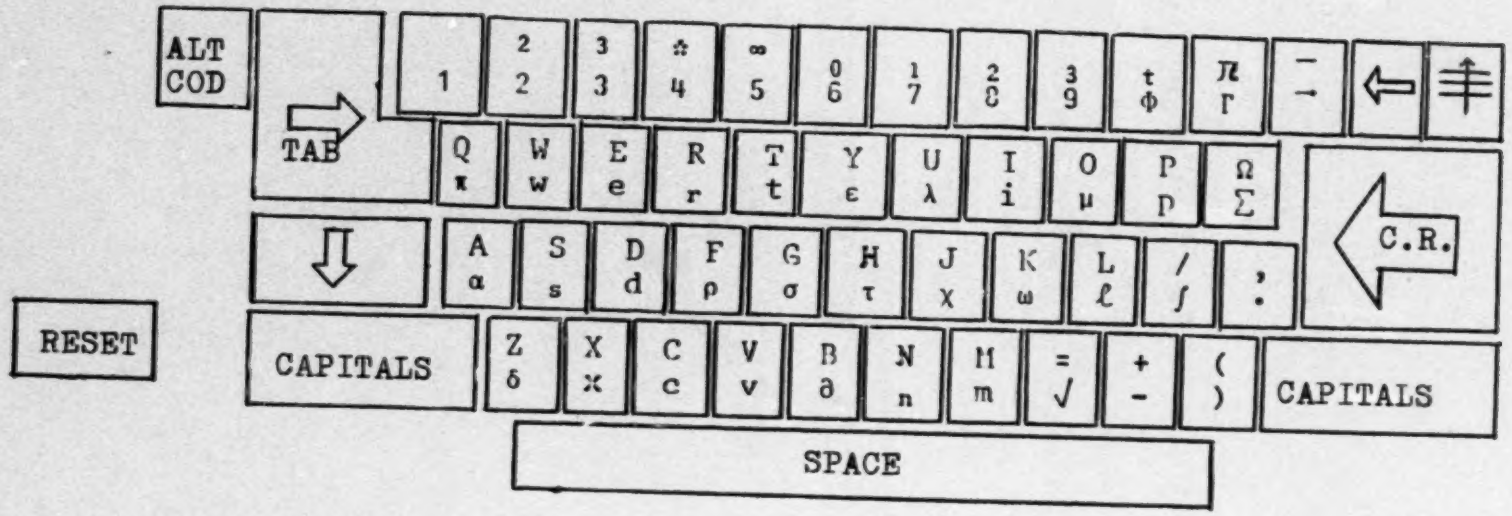


FIGURE 2

II. MATERIALS USED

In order to implement and take advantage of the questionnaires, a certain number of tools, or programmes were needed, which we shall now describe from two complementary vantage points:

1. The user's point of view.
2. How these materials fit into the software system.

1. THE USER'S POINT OF VIEW

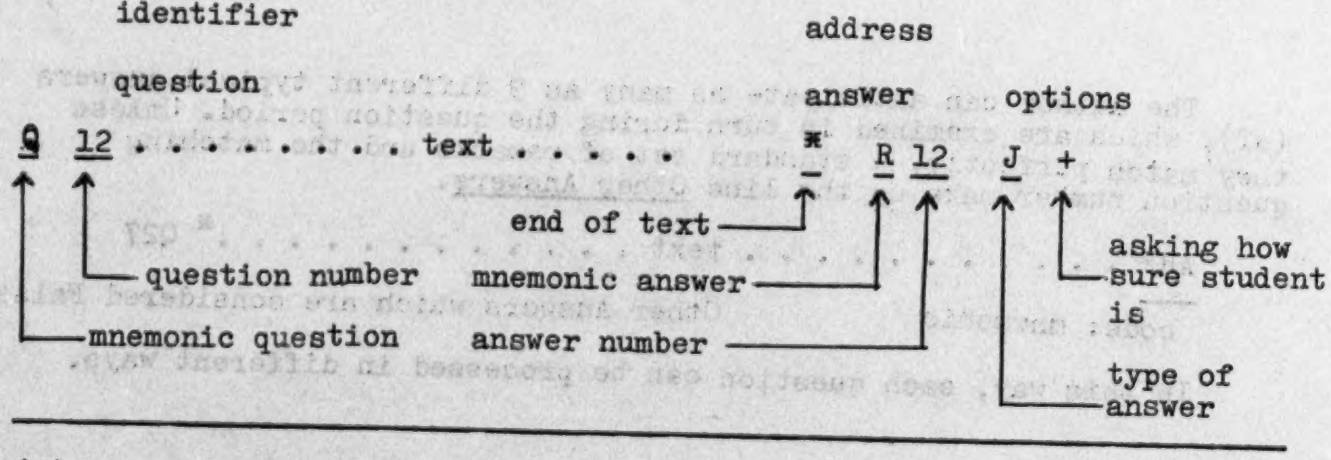
A. Author language - (L.A.)

We thought it was very desirable for the author of a questionnaire to be able to get an accurate idea of what an examination session was like. The instructional programmes must therefore be such that they can be introduced into the machine by the author himself, thereby avoiding the danger of their being altered by a technician acting as middle-man. Since the faculty members generally had had no previous training in computer technology, they needed to have a very simple method for translating a questionnaire into computer language. The Author Language was invented with this in mind.

The A.L. itself divides the questionnaire into question blocks and their corresponding answer blocks.

1. Question block

It is basically made up of the text of the question, within the framework of some code characters(1):



(1) R = Answer. J = Right.

The 4 * R 12 characters are redundant but convenient for processing. There are two options:

- the first character is J or ± depending on whether the expected answer is of the word type or formula type. The student's answer is analysed by the programme chosen accordingly (see Verbal Analysis and Formula Analysis).

- the second option character makes it possible (+ code) or not (- code) to ask the student to show how sure he is of his answer (a number from 1 to 5). This result is used for research in psychology.

2. Answer block

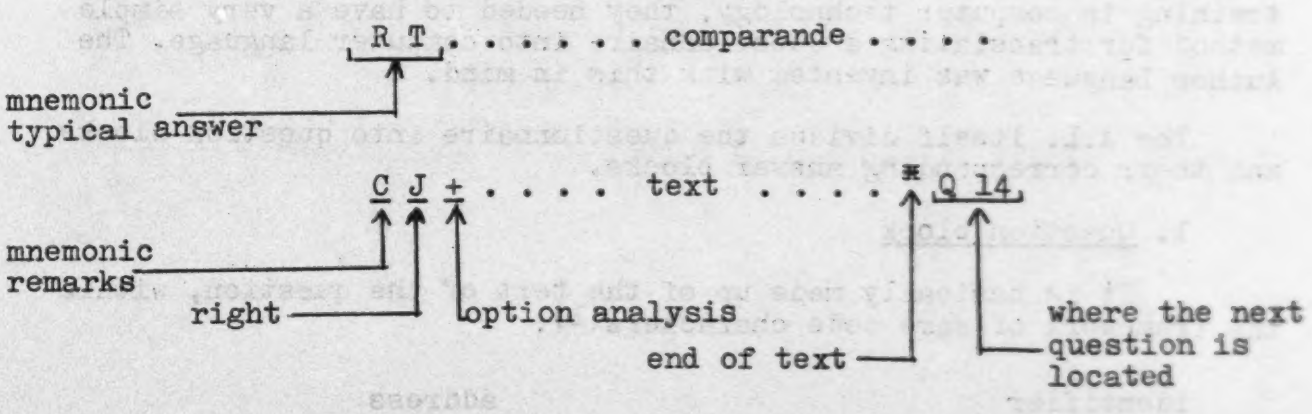
It is made up of a group of typical answers (RT), each of which is accompanied by some remarks and followed by the number of the next question.

The text of the RT is made up of one or several "comparandes", that means, the formula or the words with which the comparison is made. Next to the remarks matching each TA, a symbol is put down to indicate whether the answer is right (J) or wrong (F). Furthermore, an option character makes the work of analysing the answer more specific.

For a formula: + or -

For words: C, D, ω or δ (see analyses).

In other words:



The author can anticipate as many as 9 different typical answers (RT), which are examined in turn during the question period. Unless they match perfectly, a standard set of remarks and the matching question number make up the line Other Answers.

ARF . . . . . text . . . . . * Q27

code: mnemonic Other Answers which are considered False.

In this way, each question can be processed in different ways.

Remark

The first typical answer differs slightly from the others, in that it serves to identify the Answer Block and as a result, the RT becomes R XX (R 17, for example, where 17 is the corresponding question number).

The "comparande" which forms the answer is automatically sent on to the student (whenever there is a loop, that is to say, when the question is asked a second time and the student answers it incorrectly the second time). The student is then supplied with the correct answer, and the examination session continues with the next question.

As the system was worked out, different branching possibilities (cf. 1.2.B.) were modified for various pedagogical reasons.

Going off one question <u>forever</u> and on to the next is a move put in the category of "other questionnaires". This act is accomplished by filling out the address of the question which shows up after the remarks.

CJ+ . . . . . text . . . . .* Q17, for example, becomes

CJ+ . . . . . text . . . . .* K28-Q17, if the student wants to get hooked up with question No.17 on questionnaire No.28.

There is another way to digress to another questionnaire (cf. Associated Description Language ...).

The possibility of going back to questions asked earlier is the normal sequence, which was very rarely used, has been eliminated. Indeed, it seems preferable to find a new way to express a concept which was not grasped well the first time through.

The idea of a normal sequence was relaxed, in that side jumps no longer have to lead either back to their starting point or directly to the next question. This limitation had originally been introduced to make work easier for the writers of the questionnaires by providing them with a systematic operating flow chart.

B. <u>Associated description language</u> (L.D.A.)

The Author Language has two main disadvantages:

- sequential structure in numbering the questions.
- branching is determined by the immediately previous answer.

The first characteristic makes each question practically a prisoner of its questionnaire. Jumping from one questionnaire to another during the course of an examination session causes definite complications, and consequently must not be done too often.

The second characteristic is a pedagogical limitation which can make it impossible to follow the individual student's thought processes during a session.

Therefore, we decided to write out another language, to be introduced at a second level, to make up for the shortcomings of the basic language.

The L.A. remains, and continues to be the only way to feed texts into the machine. But those professors who have acquired a certain mastery of writing out questionnaires have the L.D.A. at their disposal. This "associated" language makes it feasible to create a new examination starting with the already extant questionnaires. All they need to do is to decide on the contents and then set up once again the sequence to be followed.

1. Symbols used

A question is referred to by the mnemonic symbol Q, followed in parentheses by the questionnaire number and the question number. For example, Q (18,12) stands for question 12 on questionnaire 18. Follow-up questions (whatever answers are given) are written out in simple chain fashion, separated by commas:

... Q (18,12), Q (11,27), Q (45,03) ...

The examination session takes place in the following pattern:

- the student's answer is normally compared with the different Typical Answers contained in Answer Block 12 of questionnaire 18.
- the connected remarks are referred on to the RT which matches.
- the number of the question given at the end of these remarks is skipped over; instead, the session moves on to the text of question 27 on questionnaire 11.

The same process is repeated in this manner after each answer. This requires the order the questions are in to be independent of the student's answers, and that is very rarely the case. Several alternative branching orders generally must be planned. The question must then be defined. Here are the symbols adopted for one specific case:

Q (17,14) = 1,4,Q(36,11), Q(42,15)

2,3,Q(54,21)

5,6,7,Q(28,07)

Interpretation

- each line defines a particular branching.
- the figures immediately to the right of the = sign stand for the different RT numbered in order starting with 1.
- after the list of figures comes the next question to be asked, followed perhaps by other questions.
- the last question, given on the right of each line, will be defined elsewhere.

If, for example, the answer the student gives happens to match the second or third RT (of Block 14 on questionnaire 17), the related remarks come up, of course, and then comes question 21 on questionnaire 54; this question is then defined just as Q (17,14) was. The "description" of an examination session is hence made by means of a set of "definitions", and each question which appears on the far right of a line must also show up on the left of an = sign. The beginning and end have special status which will be made more explicit in the example given below.

The material is put into the machine on cards (one card per line, with a rather free pattern). The syntax will be explained later in this report.

2. Extending the language

Limited to the above, the L.D.A. already makes it possible to rewrite a normal kind of questionnaire, eliminating the restrictions imposed by sequential numbering. Now let us look at the new possibilities:

- further remarks
- indicators (or flip-flop switches)
- counters
- tests for the indicators and counters

(i) Further remarks. The author can stick in extra remarks between 2 questions; the mnemonic is C, and the text is fed into the machine like a sham question followed by a simulated Answer Block. The reference number in the card file is the same as that for a question:

C(53,17)

stands for the text of question 17 on questionnaire 53 (which will be given out as a set of remarks, without waiting for an answer). These remarks follow the normal remarks connected to an RT. It is obviously convenient to group together the texts of the remarks and the sham questions.

(ii) Indicators (or flip-flop switches). The author can insert "indicators" in a line of description to follow the student's thought processes. These are simple flip-flop switches (binary position), set at zero at the beginning of the examination session, and which change when they are encountered. The mnenomic symbol is B. It is followed by a number which stands for the number of the flip-flop.

For example: Q(17,14) = 1,4,B3,Q (36,11)...
.....

means that flip-flop No.3 (set at 0) moves to 1 if the student answers in manner 1 or 4. B3 can be used again in the description: if it has already been switched on, a second encounter will make it return to the 0 position, a third will return it to 1, and so forth. How the contents of these indicators is used will be explained below.

(iii) Counters. These counters are stores in which the value judgments given to the students' responses during the examination sessions are automatically kept. The mnemonic is CTR, followed by a number which identifies the counter or its function. The counter CTR 1, for example, has the task of summing up the number of correct answers (found in each RT, on account of the letter J at the level of the code for remarks). The contents change constantly as the session progresses, and so it can be called for at any time.

A second counter, CTR 2 can be used to add up answer time, and so on. The syntax provides for adding other counters as may prove interesting.

(iv) Branching by means of indicator or counter tests. Instead of stating the next question right after an RT, the system can shunt the student off to an indicator or counter test. This makes it possible to orient him (at least partially) on the basis of his earlier thought processes or of the instant value of certain parameters.

Indicator test.
Mnemonic TI, followed by a 2-digit number standing for the indicator test number. An example of how this is written:

```
Q (..,..) = 1,5,Q (..,..)
            2,3,TI15
            4,Q (..,..)

.........................

TI15 = SI B3,1,Q (..,..)
           2,Q (..,..)
```

The TI15 test is hence simply substituted for a question, and is defined below in the same way.

SI B3 shows that the branching depends on the contents of flip-flop No.3. There are two possible patterns:

B3 is at 0: branching in 1

B3 is at 1: branching in 2

The text can deal with several flip-flops at the same time but can lead to only one branching choice:

1: at least one flip-flop is at 0

2: all flip-flops are at 1.

The counter test (mnemonic TC) is used in a way that is quite similar. The 12th counter test, for example, would be given by:

```
TC12 = SI CTRI - (8),1,Q(..,..)..
                 2,Q(..,..)..
                 3,Q(..,..)..
```

In this case, the test deals with counter No.1 (which adds up the correct answers). Its contents are compared to the number between parentheses. The branching depends upon the outcome:

If the contents are greater than 8: branching in 1
If the contents are equal to 8 : branching in 2
If the contents are less than 8 : branching in 3.

3. A concrete example of use

The following description provides the non-scientist reader with a complete illustration of the many possibilities. That all the texts belong to the same questionnaire results solely from the fact that the subject involved has not been worked out in other questionnaires.

The material below consists of:

- a description of a questionnaire (No.15) written in A.D.L.
- an excerpt from the same questionnaire.

DESCRIPTION OF QUESTIONNAIRE 15 IN A.D.L.

```
0010     S=Q(15,1)
0020     Q(15,1)=1,2,Q(15,2)
0030    2        3,Q(15,1)
0040     Q(15,2)=1,3,C(15,5),Q(15,7)
0050    1        2,4,C(15,3),Q(15,10),C(15,5),Q(15,7)
0060    1        5,6,Q(15,2)
0070    2        7,8,Q(15,4)
0080     Q(15,4)=1,C(15,5),Q(15,7)
0090    1        2,C(15,3),Q(15,10),C(15,5),Q(15,7)
0100    1        3,C(15,5),Q(15,7)
0110    2        4,Q(15,4)
0120     Q(15,7)=1,2,4,Q(15,8)
0130    2        3,B1,Q(15,8)
0140     Q(15,8)=B1,TIO1
0150     TIO1=SI B1,1,C(15,12),Q(15,11)
0160    2        2,Q(15,9)
0170     Q(15,9)=1,3,Q(15,11)
0180    2        2,Q(15,9)
0190     Q(15,11)=1,2,3,4,Q(15,15),TCO1
0200    2         5,6,Q(15,11)
0210     TCO1=SI CTR1-(6),1,Q(15,13),END
0220    1         2,Q(15,14) END
0230    2         3,Q(15,6),Q(15,14),END
0240     END
```

SOME EXCERPTS FROM QUESTIONNAIRE 15

QUESTIONNAIRE 15

```
ø8      K15         QUESTION ø1

   HERE ARE SOME UNRELATED QUESTIONS, FOR THE PURPOSE OF SHOWING
HOW CONVERSATION WITH THE COMPUTER WORKS.  ARE YOU READY?

        Rø1a+
                    **********************

        K15         ANSWER ø1
1       YES
CJ+     PERFECT
Qø1
*****
2       NO
CJ+     WE SHALL BEGIN ANYWAY
        YOU HAVE NO TIME LIMIT FOR ANSWERING
Qø1
*****
3
*****
3
ARF+    KINDLY ANSWER MORE CLEARLY, PLEASE
Qø1
                    **********************
ø8      K15         QUESTION ø2
-       WHO WAS THE FIRST MAN TO FLY
                Rø2a+
                    **********************
        K15         ANSWER ø2
1       THE MONTGOLFIER BROTHERS
CJ+     VERY GOOD
Qø2
*****
2       THE  MONGOLFIER BROTHERS
CJ+     VERY GOOD
Qø2
*****
3       MONTGOLFIER
CJ+     GOOD
Qø2
*****
4       MONGOLFIER
CJ+     GOOD
Qø2
*****
5       ADER
CF+     NO. CLEMENT ADER WAS ONLY THE FIRST TO FLY IN A "HEAVIER
        THAN AIR" MACHINE.
        THINK HARD AND GIVE ANOTHER ANSWER.
Qø2
*****
6       ICARUS
CF+     NO, THAT IS ONLY A MYTH. GIVE ANOTHER ANSWER.
```

```
Q∅2
*****
7       I DON'T KNOW
CF+     YES, OF COURSE YOU DO
Q∅2
*****
8
ARF+    NO
Q∅2

                    **************

∅8      K15         QUESTION ∅3

   BE CAREFUL ABOUT THE SPELLING, MONTGOLFIER TAKES A T
           R∅3a+

                    **************

           K15      QUESTION ∅3

1          ..
CJ+        ..
Q∅3
*****
2
ARF+       ..
Q∅3

                    **************

∅8         K15      QUESTION ∅4

   HERE IS A HINT TO HELP YOU. THE NAME IS STILL USED FOR THE
  TYPE OF DEVICE INVOLVED.
   TRY TO ANSWER ONCE MORE.

           R∅4a+

                    **************

           K15      ANSWER ∅4

1          MONTGOLFIER
CJ+        GOOD
Q∅4
*****
2          MONGOLFIER
CJ+        GOOD
Q∅4
*****
3          MONTGOLFIERE - BALLOON
CJ+        NO, IN FACT THE FRENCH WORD FOR THIS DEVICE IS SLIGHTLY
           DIFFERENT FROM THE NAME OF THE INVENTORS.
Q∅4
*****
4
ARF+       NO, THINK HARD. IT INVOLVES THE EARLIEST HOT-AIR BALLOONS.
           TRY ONE MORE TIME.
Q∅4

                    **************
```

4. Criticism and outlook

The idea of L.D.A. came into being at a time when we had not examined the notion of normal sequence. Language has a structure based on this very notion, and that brings about the following limitation (already mentioned from the original L.A.):

- any shunting off to a side question (whatever the level) must end up back at the original question or at the next question.

It so happens that this requirement is paralysing, when it comes to using the tests. As a result, it is difficult to use L.D.A., and that has been done very little up to now. Furthermore, only questions which are sufficiently separate from the context of a questionnaire can be used a second time in a description. At any rate, many extra commentaries seem to be required, but at the present time, it is not possible to string out several commentaries in a row.

It should be noted, however, that all these limitations come from the fact that the central store is small.

The current L.D.A. is hence only one stage in the development of a much more flexible language, and plans are now underway to make the major changes which are absolutely necessary. Nevertheless, the tests done up till now are promising, and have served to bring out clearly what are the desirable characteristics of a second-level language which will really perform correctly. Such a language will provide an instructor who is already familiar with how to write up questionnaires in L.A. with a tool particularly well designed to meet teaching needs.

C. How answers are analysed

An answer can be processed in accordance with any of the following three alternatives:

- without analysis
- with verbal analysis
- with formula analysis

(The type of processing chosen depends on which staff does the writing).

1. Without analysis

When this alternative is chosen, the series of characters which makes up the answer is compared directly (rough comparison) with the series of characters which was planned for by the author behind the RT code.

If the two are the same, the commentary is transmitted as planned to the terminal and branching occurs onto the question number following the commentary; otherwise, it goes on to the next RT, and so on until the ARF code is reached.

2. Verbal analysis

This analysis carries the code J in the question block (cf. description of the L.A.).

(i) Purpose. To seek out in the Student Answers (RE) those expressions which appear in the Standard Answer (RT).

"Expression" means consecutive words, where a word itself is made up of any kind of characters except those reserved to define "word limits" such as the blank space, the comma, etc. (see below at options).

Some examples of expressions:

- magnetic induction
- the little cat likes milk
- tensor
- sodium acid sulphite
- R = 23 Ω

The last of these is a formula, but in certain cases it may prove convenient to treat it like an ordinary expression.

- To detect negatives. RE and RT are considered to be the same when all the expressions requested have been found and when no negative has been uncovered, except if the answer is in the negative form. The other words which may be in the RE are overlooked.

(ii) Filling out a Typical Answer. The comparison which the author requires can have bearing on several expressions at the same time; in addition, each expression can assume equivalent forms (synonyms).

Let A, B, C be three expressions asked for, each having equivalents in A', B' and B'', C'. It must be possible, therefore, to find in the RE a way to express each of the 3 following columns:

A	B	C
A'	B'	C'
	B''	

For setting up the corresponding RT the author lays out the 3 lists end to end in a straight line. He only has to put the ⟼ sign (tabulator key on the terminal) between the lists, and the // sign (2 slashs) between the equivalents.

In other words:

RT A//A' ⟼ B//B'//B'' ⟼ C//C'

This way of writing it is logically equivalent to:

(A or A') and (B or B' or B'') and (C or C')

(iii) Options. Two kinds of independent options are available. They involve:

a) the order

b) the characters for separating words in the RE

When several different expressions do indeed occur, the order in which they appear in the RT may or may not determine the quality of the answer. Furthermore, it is immaterial in French how words are surrounded by blank spaces, commas, periods, and apostrophes. In the case of mathematical "words", such as R = 2,3Ω or A.B, or even D'=D, the decimal point, scalar product and the prime sign are normal characters. Only the blank space continues to serve as a way to separate words. Consequently, on the level of the commentary connected to each RT, the author must use a letter to specify which option he has chosen. One of the 4 codes given in the latticework which follows, which summarises the 4 possible combinations, is put down after the CJ (or CF):

	Order	Disorder
blank space.,'	O	D
complete blank space	ω	δ

(iv) Examples

a) Q12 In order of decreasing electronegativity, state the names of the different halogens R12J+

R12 They are fluorine, chlorine, bromine and iodine

CJO *Q13

RT FLUORINE ⟵ CHLORINE ⟵ BROMINE ⟵ IODINE

CJO Very good. *Q13

RT IODINE ⟵ CHLORINE ⟵ BROMINE ⟵ FLUORINE

CJD Yes, but you gave them in the wrong order. Answer again *Q12

b) Q17 What is the resistance R and the intensity I flowing there *R17J+

R17 R=2.3Ω//R=2.3 OHMS I=0.4 A//I=0.4 AMPERE

CJ∫ Good *Q18

3. Formula analysis

Whenever the answer appears in formula form, it is impossible, first of all, to anticipate all the equivalent ways of writing it, and secondly, it is not desirable to introduce very rigid limitations on ways of writing, such as fixing the order in which variables are given, positioning parentheses and quotients, and so forth, which would tend to make using the system cumbersome.

As a result, it became necessary to plan a programme which, to a certain extent, would analyse the student's answer, the one expected by the staff that wrote the programme, and which would then decide whether they amount to the same thing.

From a theoretical viewpoint, this problem is a rather complex one, so that we shall consider here only the aspect of it which deals with "practical applications".

A syntax for the formulae used is worked out. This syntax is described in the programme by "context-free" rules of the type

<formula> → <relationship> < formula end character >

<relationship> → <side of equation> <relationship operating sign>
<side of equation>

<relationship operating sign> → =, SUP, INF

<side of equation> → <term>
→ <side of equation> ± <side of equation>
→ <term> / <term>
etc...

In practical application these rules will fix the restrictions set on programme writing, which in turn will define the limits of the operating signs and the relative substitutability of the different symbols (cf., appendix on "Restrictions on programme writing").

These rules enable us to analyse a formula at the input point and to decide whether or not it belongs to the L(G) language which we have defined, that is, whether or not it is syntactically well formulated. It is worth noting, however, that the syntax was defined only for a subset of the set of possible formulae, so that certain cases will not be analysed (expressions containing a vectorial product or an exponential equation).

If a "mistake in syntax" occurs, a message is sent to the student, who can then suggest another answer, for it is important not to penalise a careless error or a mistake in typing.

Once the formula is syntactically acceptable, it is put in conventional form so that it can be compared to the standard answer

(which is also stated in conventional form when the questionnaire is entered on diskpacks).

The process consists of rewriting every single relationship in the form of a series of signed terms, such that the second side of the equation equals zero. It is generally made up of

- expanding the parentheses
- reducing to the same common denominator
- rearranging factors and terms in a given order
- simplifying (in certain special cases)

The comparison results in dividing things in two. One does not strive to fix semantic meaning on missing items. If the two do not match perfectly, the answer is considered false and is processed accordingly.

Example:

Typical answer	:	$\text{ROT } \vec{H} = \vec{i} + \varepsilon_o \partial_t \vec{E}$
Conventional form	:	$-\vec{i} - \varepsilon_o \partial_t \vec{E} + \text{ROT } \vec{H} = 0$
Student's answer	:	$(\text{ROT } \vec{H})/\varepsilon_o = \vec{i}/\varepsilon_o + \partial_t \vec{E}$
Conventional form	:	$-\vec{i} - \varepsilon_o \partial_t \vec{E} + \text{ROT } \vec{H} = 0$
Judgment	:	Correct

Moving from one standard answer to the next is done in the same manner as in processing without analysis (CF II-1C1). Moreover, this is true no matter what kind of analysis is asked for.

D. DCM - Information system during questioning

1. Description

The goal which was set up was purposely limited to allowing the student to have access to definitions coming from a recorded dictionary, while the questionnaire is being used. This dictionary is input by the authors according to the needs they anticipate for each questionnaire. Under present conditions there is no protective device, so that students have the entire dictionary at their disposal. From an instructional point of view, making information available to the student forces him to be more active and stimulates snatches of dialogue which replace the habitual "tutorial" method of teaching. That reflects a need which the authors and the students often feel. In addition, the questionnaires can partly be relieved of their "introductions" which are often long and tedious. The system is not fixed once and for all - improvements are planned. The description which follows shows the present experimental stage of development. It enumerates the various operating steps: steps the student takes to get information, and steps the authors take to supply and keep the file of definitions up to date.

2. Definition keys

All student or author operating steps must include a definition key which may be:

1. An isolated word (Example: PHASE)

2. An expression of the "Law of" type: (Example: LAW OF PHASES)

The expressions currently allowed have the form:

$$\left\{\begin{array}{l}\text{LAW(S)}\\ \text{EQUATION(S)}\\ \text{THEOREM(S)}\\ \text{RULE(S)}\\ \text{RELATIONSHIP(S)}\end{array}\right\} \left\{\begin{array}{l}\text{OF}\\ \text{OF}\\ \text{OF}\\ \text{OF}\\ \text{OF}\end{array}\right\} \left\{\text{word}\right\}$$

3. Any sort of expression whatever (the difference being that in 2 condensation is involved).

The definition check may include as many blank spaces as necessary (they are later eliminated). Back-spacing in order to make corrections is allowed in the key and the definition.

The length of the keys is not limited. Nevertheless, it is important to know that some truncation may occur after condensation.

3. Capacity

The length of the definitions is purposely limited to about one hundred characters. A gimmick can be used for longer definitions: words are defined in a chain, in which the first definition contains a word which is defined elsewhere, and so on. The file currently being used can contain 1500 definitions.

4. Student operating control

Each time it is the Student's turn to take over, he can call for information in the following manner:

"DCM Key

For example: "DCM "PHASE (as many blank spaces as are needed)

He receives the definition or the message NO INFORMATION. He can then continue the questionnaire he is in the midst of doing by answering the question which was asked, or else he can make the next student operating move.

Spelling mistakes are not accepted. This limitation is by no means unreasonable, since the words whose definitions are being asked for are usually printed in the text of the questionnaire.

5. Author operating control

- Cataloguing: This operating move takes the form:

DCM [*] Key Password = Definition

Example:

DCM PHASE = HOMOGENEOUS PART OF A SYSTEM

Altogether it must not require more than two blocks (120 characters).

The system sends the message DONE if the definition is a new one, otherwise REVIEW DONE.

- Erasing: Erasure is accomplished in the following way:

*DCM *DELETE Key

Example: *DCM *DELETE PHASE

The system sends the answer DONE or a message 'R' if there was no purpose to the operating move.

Note: The Author Operating Control moves can be executed during the session.

6. Single-character messages

The system sends these messages to signal that something has gone wrong:

∞ wrong operating move (the three-letter operating code is not DCM, nor any of those recognised by the system)

* the asterisk at the end of the definition is missing

= the equals sign at the beginning of the definition is missing

The other messages are for use within the system. For example, P indicates that both the available track and its corresponding emergency track are full.

7. Inventory of recorded definitions

An inventory programme for definitions or a file is available for the authors. It is called for from the computer console. Its name is LST DOC.

8. Recording requests for information

During a session, a special command desk - usually the instructor's desk - makes up a list of the requests for information (definition keys) which the students have made, placing +DCM in front if these requests have been satisfied, and -DCM if they have not been. There are several instructional advantages to this:

- A statistical study of requests for information
- Improving the information file
- Improving the questionnaire by adding to it the frequently asked for definitions
- Statistical evaluation of the students' level and the gaps in their knowledge.

Probably some of these interactions will be made automatic. That would represent the next step in progress towards a freer dialogue between the student and the Computer - aided Instructional System.

E. Programmes in use

1. Orgadiag programme

Description of how it is used. This programme comes into play when a questionnaire is typed out on a deck of cards. It uses the deck to supply two types of information.

- Operating programme: An operating chart giving the logical form the questionnaire should take is sketched out by means of a rapid printer.

- Checking the syntax: While the operating programme is being printed, the deck of cards is checked out so that it agrees with the syntax of the Author Language. If there is a mistake, an accurate prediction of the card involved and the column number on that card are provided. Besides actual errors in syntax (invalid codes or codes in the wrong order), other common mistakes (for example, finding a card which does not belong in this deck) are spotted.

This programme is a vital step between typing or key-punching the questionnaire and feeding it on to discs. Indeed, putting a questionnaire on discs which has the wrong syntax sometimes brings about unexpected results.

2. Punching the questionnaires

The input procedure for a questionnaire written in Author Language includes the intermediary step of establishing a deck of punched cards. Due to the fact that we are using a set of special characters, it is not possible to perform this operation on key-punchers. Therefore, the 1052 consoles were used for this purpose. The punching programme

- manages the terminals
- checks at every step of the way to see that the question blocks and answer blocks are built in accordance with the rules laid out by the L.A.

3. Listing

Every questionnaire put on discs should be able to be listed at any time. For the same reasons as given above (the rapid printer is equipped with a standard chain), this operation must be done using the

1052 console. Whatever questionnaire is used, the listing which is done contains each question, followed by its related answer block and all the relevant code indications, identifiers, and so on.

4. Recording and issuing unexpected answers

Each time the ARF output of the Answer Block is used (cf. Author Language II 1C), i.e. each time an answer is not analysed, it is recorded on a disc. One or several of the desks can print out the list of unexpected answers at the end of an examination session or workday on one or several terminals. This list contains the unexpected answers sorted by questionnaire number and question number, as well as by registration number in the author's student-file for each such answer.

5. Handling and processing student data

While an examination is going on, the following data is recorded for each question answered by each student:

- the outcome (right or wrong)
- the amount of time the student took to answer
- how sure the student is of his answer

By using this data, the thought processes of the student in the course of the examination (sequence of questions and answers, outcome) can be followed, and statistical records for the questionnaires can be set up.

2. HOW MATERIALS FIT INTO THE SOFTWARE SYSTEM

A. Basic system

The software which the constructor delivered includes two systems: the Basic Operating System (B.O.S.) and the Disk Operating System (D.O.S.).

Each of these two systems is based on a disc. Moving from one system to another is done by replacing the disc on the 2311 disc unit. Different programmes which are in use enable the user to cut down, increase or modify the possibilities of a system depending on his needs:

- an initial loading programme (IP2)
- a supervisor programme
- inspection and service programmes
- compiling programmes
- commercial programmes

The supervisor's tasks can be summarised as follows:

- processing interruptions

- handling input-output requests
- processing programming errors and input-output errors.

We should call special attention to the "FETCH" supervisor sub-programme, which makes it possible to place in the central store and carry out immediately any of the programmes recorded on discs in untranslatable binary form (CORE IMAGE LIBRARY file).

The essential difference between the B.O.S. and the D.O.S. is in the nature of the programming languages which can be used with each system.

The B.O.S. only has an assembler and a compiler for Report Programme Generator (RPG) language, which is useful solely for commercial applications.

The D.O.S. also has a FORTRAN compiler. However, a system which includes a 6K eight bit byte supervisor and programmes that are complicated enough to handle input-outputs on diskpacks demands too much central storage space for us to use it in our experiment at the present time.

1. Modifications made in the B.O.S. system

For want of storage space, we were not able to utilise the D.O.S. Furthermore, the B.O.S. as such was not appropriate for our particular experiment. We nevertheless preferred to hold on to the B.O.S. and modify it for our purposes, rather than to completely rewrite a system adapted to our needs.

These modifications can be put into 2 categories.

(i) Local modifications. The result of these was to clearly improve the usefulness of the B.O.S., especially by increasing its performance and by creating system service programmes. The modifications consist of:

- Eliminating reading inspection cards, by means of a programme hooked up directly to the control panel.
- Automatic loading of phases, or of modules recorded on discs, available for use immediately, or returned to the programme calling in (macro LOAD). This change makes it possible, in particular, to keep the system updated, and to adjust directly any programme on file in the Core Image Library.
- Adapting the D.O.S. macros CALL, SAVE, RETURN for the B.O.S. system.
- Writing a "disassembly" programme or reconstructing an assembly progress on the basis of binary codes. This programme is especially interesting when it is necessary to alter or patch up a "constructor programme" for which the listings are not available.
- Writing service MACROS.

(ii) Writing a programme to handle messages for the 1052. Since the 3965 is not run by the B.O.S., it is necessary to write input-output sub-programmes for the 2701-3965 combination which are compatible with this system. How this programme is hooked up with the application programme is described in the next paragraph.

B. Application Programme

This is the term which covers all the programmes involved in practical applications and which are organised around a resident component which we call the "core".

This core serves to handle the message input and output lines, and to call up from the central memory the various programmes required to process a given input message. These programmes are called upon by means of the supervisor's FETCH macro which we adjusted in the following way. Instead of reading the entire system dictionary on diskpacks, we created a tiny dictionary of the phases used in questioning and we put this into the central store. This modification makes it possible to avoid long and useless disc readings.

The core's structure is given in Figure 3. The non-permanent programmes are brought to a relay area which is described in Figure 4, which shows how the system is input into the store.

FIGURE 3

STRUCTURE OF THE CORE

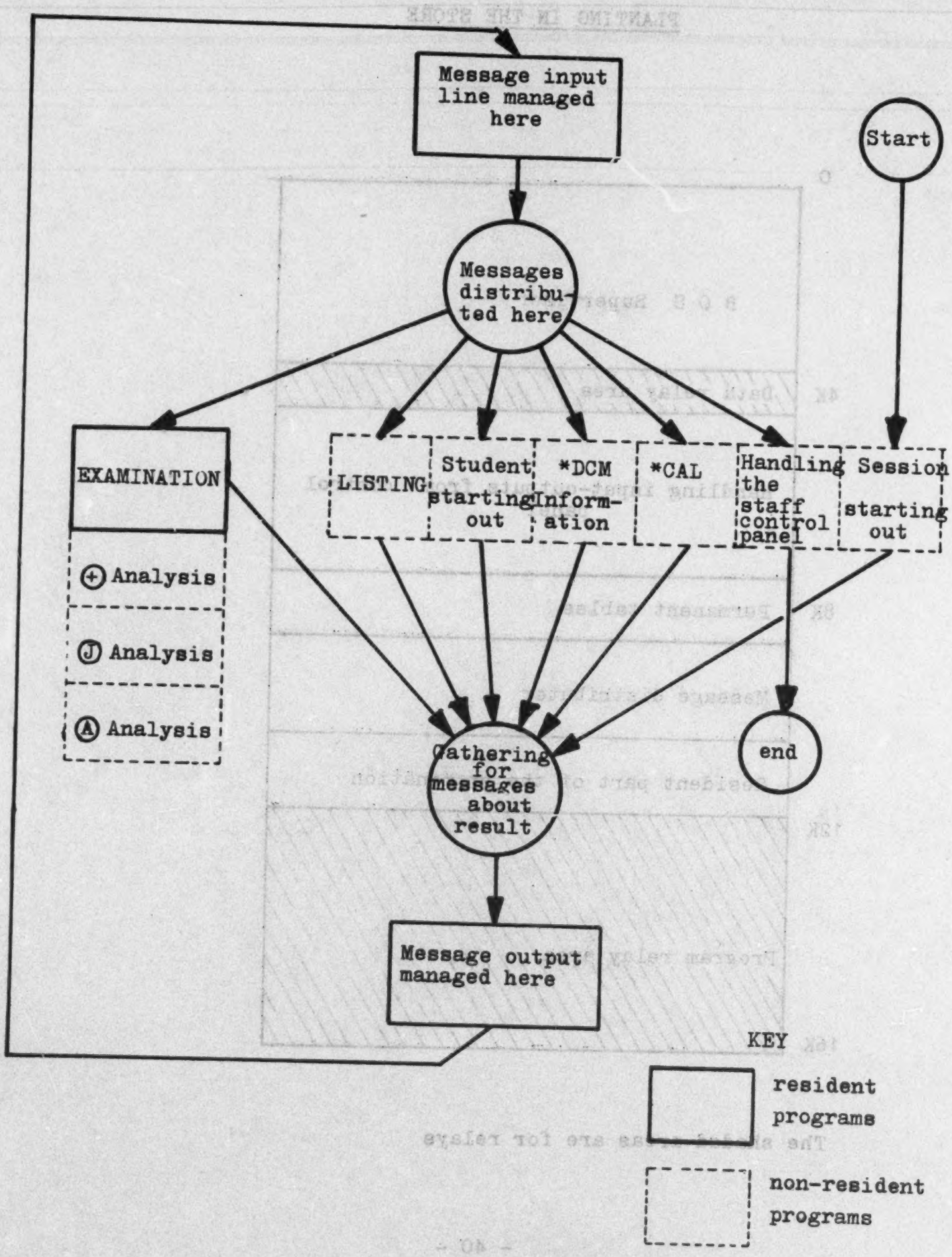
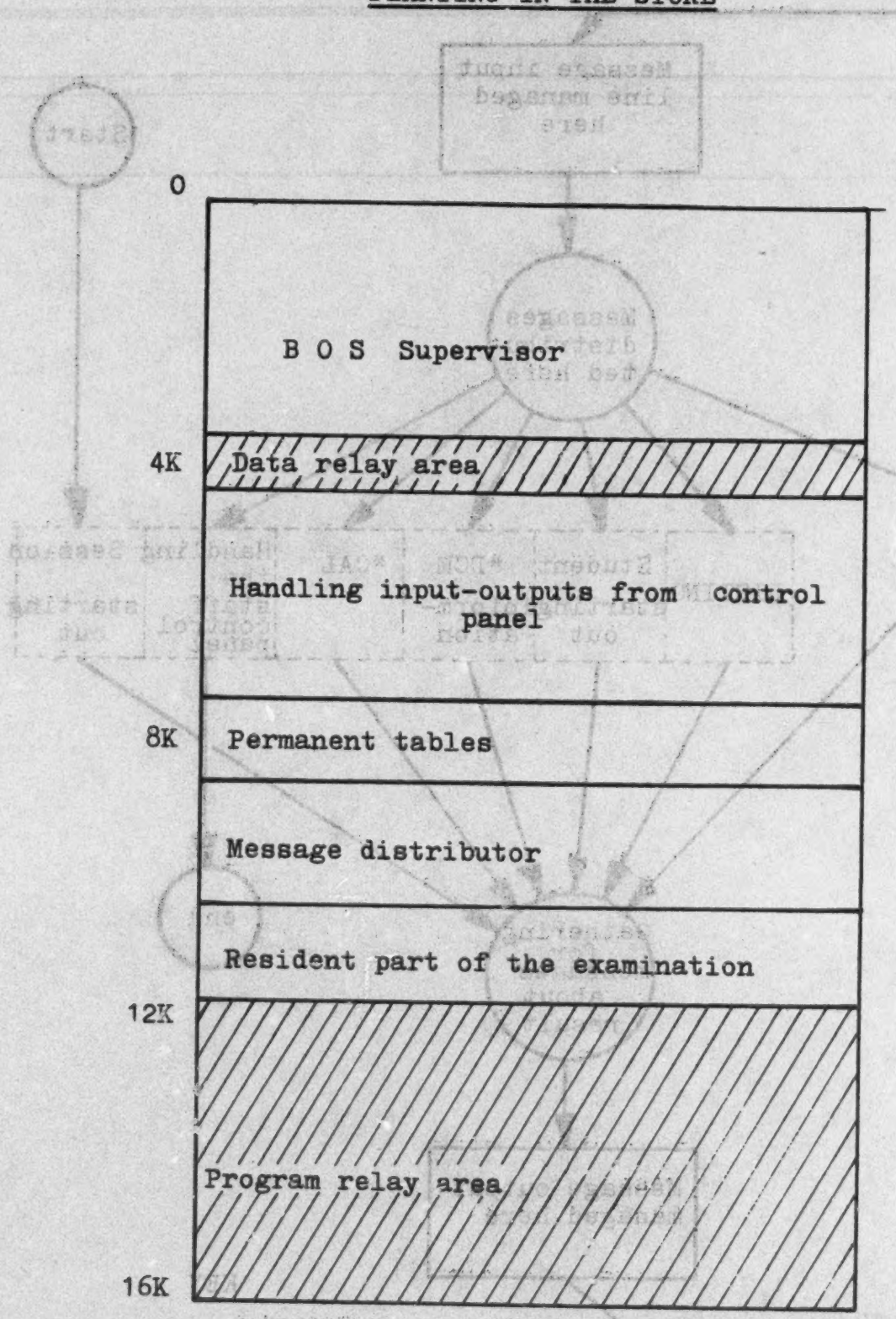


FIGURE 4

PLANTING IN THE STORE



The shaded areas are for relays

III. APPLICATIONS

At the present time, the experiment has expanded to include teaching staffs in a number of fields.

- Physics	1st year M.A. level
- Biology	Undergraduate major
- English-language linguistics	1st year M.A. level
- Discussion classes in Calculus	Beginning undergraduate level for physics and chemistry majors

In addition, the Student Computer Laboratory (OPE) has begun to work with some professors teaching Physics to undergraduates. This co-operation ought to grow this year, since four professors have been granted temporary half-time assignments to our staff by the administrative authorities in charge of instruction and school programmes.

1. HOW THE PROGRAMME WAS APPLIED TO PHYSICS

The library of questionnaires on the physics course at present contains 35 questionnaires on the syllabi of courses leading to the M.A. degree in physics.

As will appear from what follows, this experiment lent itself to other fields, such as biology, English-language linguistics, and classroom discussion work in numerical analysis. In this chapter, however, we will only deal with what is relevant to the problems that cropped up in the course of work on the physics questionnaires and the materials which the team of computer experts came up with to help the instructional staff solve them.

A. Perfecting the questionnaires

Once the subject matter was selected and delineated during the meetings which the instructional staff had with the professor in charge of the main lecture course, we found we were dealing with some 25 to 30 units covering the material of the undergraduate Electricity course.(1)

---

(1) After the M.A. programme in Physics was reorganised into four major courses (Certificates 1,2,3 and 4) with syllabi different from those of the old undergraduate physics programme, we broadened our field, but the methods used to debug the questionnaires developed very little. At the present time, we are trying to systematise the way the questionnaires are written by using the help of a team of psychologists. However, this aspect of the project is barely under way.

To begin with, each of these units was entrusted to a team of two teachers who were to take charge of the resulting questionnaire. The first step was then to work up an outline for the questionnaire, which was then discussed by the full teaching staff. After this initial discussion, a temporary draft taking the remarks made into account was made, typed up and fed into the machine.

At a full test meeting of the staff, the questionnaire was then reworked, criticised for both form and content, sometimes flipped completely around, and always filled out and made more accurate.

Student membership in the groups working to write the questionnaires led us to change our methods slightly, having each group keep up with its questionnaire until final testing, though some members of other groups would also be involved by that stage.

Once the subject is chosen, the questionnaire is thrashed out with the following moves:

- Deciding what kind of questionnaire:
  - Questionnaire in which emphasis is put merely on testing.
  - Questionnaire in which the goal is to get a law stated, or more exactly, its symbolic formulation.
  - Questionnaire in which only the basic concepts are made explicit.
- Deciding on the normal sequence and the order in which the steps should be taken.

  Out of all the notions which come up during a study of the subject chosen, which ones are directly connected to reasoning and thereby merit a place in the normal sequence.
- Deciding on the questions for a derived sequence.

  Starting with the outcome of the previous choices, their formulation in question form, and the standard type answers that they call for, one can move on to building up questions in derived sequence.

B. <u>Writing the questionnaires</u>

1. <u>General goals</u>

The following points have been emphasised:

(i) Need to establish the <u>precise teaching goal</u> of each questionnaire. In particular, how does the teaching occurring here fit in with the lecture course and the discussion sections.

Practical example worked out: concentrating on some basic notions which often prove difficult for students to handle (in the questionnaire which was used, concepts of macro-

scopic and microscopic states and their relationship to concepts of probability were involved).

(ii) Need to establish the goals expected from analysing the results. These goals can vary: feedback on the course or on the discussion sections, analysis of how concepts are learned, relationships between concepts, student thought processes, causes of error, etc. It is difficult to reconcile all these goals, and the questionnaires do not necessarily take the same form for various situations, so that it is necessary to select some of them beforehand as the chief goals.

(iii) In every case the questionnaire must be designed to satisfy these purposes as much as possible. That assumes that experiments will be used to check up on how adequately the rules for design match the goals which have been established. Those writing the questionnaires are obviously intimately involved in this aspect of the work.

2. Method used

The questionnaire deals with the binomial law - it aims at making the student go over some notions (cf. III-B-1-i), and attempts to analyse the largest possible number of probable errors and their causes, and to rectify the situation. Hence, it is designed to make an initial breakdown of errors. Drawing up the questionnaires was done in several steps.

(i) First draft, written in the style in which it is given to the students. The goal was to see how big the subject is, how it can be outlined, how much data need be presented, how long it should be, etc.

(ii) Analysing this first draft. The purpose of this analysis is to pick out:

- the notions introduced in the statement
- the notions which the student is assumed to know
- an analysis of the form the questions take: what concepts or string of concepts are they based on?
- an analysis of the reasoning process required to move from the question to its answer: locating all the steps which the student must take to answer correctly (obviously the level on which this analysis is made must be related to how much the student is assumed to know. The level is correct when no mistakes show up on material of lower levels).
- the foregoing analysis should make it possible to sift out beforehand certain kinds of errors and their causes. It is then feasible to correct these errors by supplying an explanation appropriate to the specific kind of error made right after the wrong answer. Such explanations and side-tracking hence need to be planned out in the same way as the main questions.

(iii) Analysing the main questions as well as the explanations and sidetracking makes it possible to present the questionnaire in an advanced stage of development. A sample worked out for the bionominal law is available for those questionnaire writers who may be interested.

(iv) Writing the questionnaires in the final form in which it is given to the students occurs only at the last stage of development. The sole aim is to make the hypotheses and questions easy to understand. A second reading by people who are not familiar with the material is done to check that the statements are phrased clearly.

(v) Two tables summarise conveniently the basic contents of the questionnaire. The first, which deals with the questions, has been set up in the following manner:

Question number	Question content	Notions which have to be understood in order to answer	Characteristic expected answers	Uncharacteristic expected answers
...		Contents of explanation connected to the answer	Place where the answer is to be sent	

A second, "vertical" table can be set up in the same way. Its purpose is to classify the various concepts rather than the questions.

These two tables prove very useful in examining the answers.

3. Some rules for design

A goodly number of more or less contradictory requirements made it necessary to set up some fundamental rules of design which aim especially at controlling the outcome of the experiment better. Obviously these rules are not unalterable, and it would be wise to investigate their influence by testing questionnaires which adhere to different rules.

(i) the total number of notions which occurs in any one questionnaire should be very small, if the student is to be able to check on whether he has assimilated all these notions, and if it is desirable to find out efficiently from the results whether the student has assimilated them or whether his mistakes have been corrected. At this juncture, the exact number of such notions has not been determined, but it seems reasonable to expect it to be considerably less than the total number of questions.

(ii) Generally the student must have mastered several notions to answer any one question correctly. To test whether a notion has been learned (that is, can be used correctly), the same

notion must therefore appear in several answers, which can then be examined in a single batch tied together by the notion being tested. For the moment, this is not an easy rule to apply, but it should make it possible to make a breakdown of the answers notion by notion. At any rate, it assumes that the analysis mentioned in III-1-B2 (ii) has been accomplished accurately.

(iii) At most the questions should have bearing on types of reasoning. Thus, it is necessary to avoid:

- questions which essentially require the student to do a lot of figuring
- questions whose answers can be memorised.

These two points are studied by special questionnaires which raise specific problems. Nothing is gained by mixing them in with the others. This has some repercussions on the choice of subjects for the questionnaires. In particular, in questionnaires dealing with problem solving exercises or with theorem demonstrations, it seems rather difficult to avoid the two kinds of questions mentioned above. It is therefore better, at least for the present, to avoid this type of questionnaire.

(iv) Explanations connected with wrong answers serve to draw the student's attention to the mistake in reasoning which he has made. Hence, they should not contain the full answer to the question, but only an aid to correct the line of reasoning. The logical conclusion of this should be an "Answer once more" which allows the student to set his thinking on the right track and allows the author of the questionnaire to check whether the scheme for diagnosing errors is adequate.

The sidetracking questions are put with the errors which have bearing on the student's understanding of one of the key concepts of the problem.

(v) The policy was adopted of making no comments whenever the answer is correct. It is hence assumed that the student has understood the line of reasoning required to give the answer. Studying all the students answers should make it possible to verify this hypothesis. It should be noted that this practice probably makes the teaching process less efficient. The student can indeed come up with the correct answer for the wrong reason. It would be possible to supply a commentary taking the form of "Right answer. Indeed ...", in which the right line of reasoning is explained. In this case, each student can compare his own thinking with the correct approach, and adjust his own thought processes if necessary. On the other hand, adding information in the form of explanatory commentary for accurate answers would obscure one of the purposes of the experiment, that of seeing how the student has learned and uses what he has come across in lectures and discussion sections. Thus, it is necessary to keep to a minimum the practice of supplying extra information (for this

type of experiment) and to strive to control its impact on what the student already knows (what he has gotten from the course, etc...).

(vi) Repetitions in the way the questionnaires were stated were intentionally limited as much as possible. This has a number of drawbacks, especially on account of the form in which the questionnaire is shown to the student. It is worth noting that the reverse choice is a delicate business (useless and impossible lengthening of the form, or else limiting it to only those items required by the question - in which case, any attempt on the student's part to organise and sort out is excluded). This point ought to be studied with care.

(vii) As few notations as possible were introduced, even if that means that the problem loses some of its scope. This was made indispensible by the difficulties in machine writing and the dangers of improper confusions between notation used in a statement and a different notation system which the student may have picked up elsewhere (for example, in the coursework). In any case, the problem of having different codes has not been solved adequately.

(viii) There is still a touchy problem in how to process answers which were not anticipated. Experience shows that it is not enough to provide an explanation or a side track after such an answer, for that cannot remedy the kinds of mistakes which have not been identified. The only possible solution is an empirical one: making this category smaller by studying the answers supplied and by processing appropriately those answers which can already be diagnosed. This assumes close co-operation between the staff writing the questionnaires and that which examines the outcome - an understanding that those writing the questionnaires will follow the work of analysing the results - a need to agree on the precise goals which the questionnaire is to reach before it is actually prepared.

2. USING MINITRAN AND SIMPLE LANGUAGES, AND DISTRIBUTION CLASS WORK IN MATHEMATICS

A. Minitran and how it is used

The presence of numerical applications in the questions which the system asked students during computer questioning sessions led us to conceive of a programming language which would be simple enough to be used by students who are not computer specialists and which would have a compiler appropriate for the small size of the memory store of our machine.

At any point, the student can call upon the calculating apparatus by typing on his terminal the characters *CAL followed by his programme at the beginning of the line. Analysing and carrying out the operations are then done in a conversational pattern. One or several arithmetic expressions can be evaluated, if need be with different numerical data. When the student receives the results of his calculations, he goes back to the examination session at the point he left it.

The Minitran programme is written on a single line of the control panel (120 characters). This short programme option has the advantage of leading to swift compilations and operations. As a result, the time the student needs to answer is acceptable for both the control panel asking for the computation and for the other control console being used during the questioning session.

The instruction "repeat" makes it possible to have some computation algorithms which includes a repetition with a definite number of loops (Fortran's DO type).

The Minitran language was hitched up with the questioning system and has been functioning since December 1967. It has been noticed that, in actual practice, few instructional programmes use this possibility of making computations.

On the other hand, the ease with which this language is used made it possible for entering undergraduates (in the MP and PC groups) during the 1967-68 school year to make practical use of this computation facility, aside from any examination purposes.

Let us give an example of how this language is used.

"Calculate the potential electricity produced by a basic charge e at a distance of 1 angström".

- Normal way to write the problem: $V = e/4\pi\ell_0 R$

$\ell_0 = 1/36\pi 10^{-9}$ MKSA

$R = 10^{-10}$ METER

$e = 1$ FARADAY$/N_0$ =

$96490/6.025\ 10^{23}$

- Programme's way:

```
*CAL ℓ0 = 1/(36*Π*109)*    R = 10 - 1Φ
e = 9649Φ/(6.Φ23*1825)*
V = e/(4*Π*ℓ0*R)* WRITE (V)*
```

In other words:

```
*CAL  V = 9649Φ/6.Φ25825/(1Φ - 1Φ/109)*  WRITE (V)*
```

In actual use, Minitran proves not to be quite appropriate for introducing students to programming and methods of numerical computation. It has the following shortcomings:

- the source programme is not sufficiently long

- there is no opportunity for partial correction of programmes
- there are no tags, hence no conditional or unconditional jumps
- there is no panel.

As a result, one is led to devise another version of Minitran and to add to it a control language, in order to make up for the weaknesses mentioned above.

B. Symple and how it is used

A new conversational system called SYMPLE (Système Multi-Pupitre à Langage Evolué) has been developed. Here is an example of how this language is applied.

"Programme for solving a second degree equation"

U = User S = System

```
U.  /PRG
S.  READY
U.  1        $1 — READ (A,B,C)
U.  2        D = B**B - 4**A**C
U.           IF(D)5,6,7
U.  5        TXT(NO REAL ROOT)'VRS1
U.  6        TXT(DOUBLE ROOT)
U.  7        X1 = (-B+√(D))/2A'   X2 = -B/A - X1
U.           WRITE(X1,X2)
.
.
U.  /EXC
.
S.  7        X1 = (-B+(D))/2A'X2 = -B/A.- X1
S.  ERROR 6  COMPILATION CANCELLED
.
U.  7        X1 = (-B+√(D))/2A'   X2 = -B/A - X1
S.  CORRECTION MADE
.
U.  /EXC
S.  TYPE $3  DATA PLEASE
U.  2,5,2
S.  NO REAL ROOT
.
S.  TYPE $3  DATA PLEASE
```

```
U.  2,4,2
S.  DOUBLE ROOT
S.  X1 = -1      X2 = -1
S.  END
.
U.  /INS 9,7
S.  READY
U.  9            X = -B/2A' WRITE (X)' ART
S.  CORRECTION MADE
.
U.  /LST
S.  1            READ (A,B,C)
S.  2            D = B*B-4*A*C
S.               IF(D)5,6,7
S.  5            TXT(NO REAL ROOT) 'VRS1
S.  6            TXT(DOUBLE ROOT)
S.  9            X = -B/2/A' WRITE(X)'ART
S.  7            X1 = (-B+√D))/2/A'X2 = -B/A - X1
S.               WRITE (X1,X2)
.
U.  /EXC
S.  TYPE ϕ3  DATA PLEASE
U.  2,4,2
S.  DOUBLE ROOT
S.  X = -1
S.  END
.
U.  /EXC
S.  TYPE ϕ3  DATA PLEASE
U.  1,4,2
S.  X1 = -5857868   X2 = -3.414213
S.  END
.
U.  8            WRITE (X1,X2)' VRS 1
.
U.  /ANV
S.  WRONG MACHINE OPERATION
U.  /HAVO
```

```
S.  CORRECTION MADE
U.  /LST
S.  1          READ (A,B,C)
S.  2          D = B*B - 4*A*C
S.             HIF(D)5,6,7
S.  5          TXT (NO REAL ROOT) 'VRS1
S.  6          TXT (DOUBLE ROOT)
S.  9          X = B/2/A'  WRITE (X)' ART
S.  7          X1 = (-B +√(D))/2/A'X2 = - B/A - X1)
S.  8          WRITE (X1,X2)' VRS1
```

This programme will be handled by the computer starting with the first line of instructions. The system thus starts by asking for the 3 data which it will assign to A, B and C respectively. Then the value of D is calculated. Next, it considers 3 possible cases:

- If D is negative, it goes to line labelled 4: print out a text, then go towards 9, that is, ask for 3 other data.
- If D equals zero, move on to line 7: print out a text, then continue in order by line 5.
- If D is positive, move to line 5: compute the 2 roots, then print them out.

In the latter two cases, the command to stop is finally reached.

C. Mathematics discussion section

The Symple system is used for work in mathematics for small discussion classes, and for introducing programming. These sessions addressed especially to beginning university students, took place two full days per week, and thereby we were able to accommodate several hundred students.

The Minitran 2 conversational language is sufficiently simple for a student to assimilate it in a few hours. The first sessions were devoted to making up small programmes for ordinary computations, deling basically with numerical applications but also requiring some logicl decisions at the operations level. (For example: second degree equaion, prime numbers ....).The computer's resources were quickly put to us in order to work on less hackneyed programmes.

Each session began with a brief report on the techniques of stadard numerical computation. The interesting part is the comparison made ith methods specially designed for automatic computation. Discussion ofthe degree of accuracy of the results, for example, can be the stepping stone to a detailed study of algorithms, and demonstrates the basic difference which exists between manual and automatic techniques (Exmple: calculating a determinant, reversing a matrix, roots of algebraic o transcendent equations).

In addition to purely numerical applications, logical manipulations were carried out, which led once again to choosing between algorithms. The problem of sorting a file supplied a particularly clear example, and gave rise to a wide variety of procedures depending on the type and size of the file involved.

These sessions enabled the students to get a better idea of what uses a computer can be put to, and especially of the difficulties involved in formulating a problem accurately. The inflexibility of a computer makes it necessary to analyse a problem more thoroughly than usual. It is also worth mentioning that we organised similar sessions on a lower level when we invited in groups of high school seniors. Many of them got very excited (enough to come in on Sunday) and designed programmes with astonishing cleverness and spirit.

3. BIOLOGY

A. The group of biologists

After a meeting at which biology professors were informed of the possibilities presented by the Student Computer Use (Ordinateur pour Etudiants - OPE), a group of six assistant professors of animal biology, teaching at the undergraduate level, got together to try an experiment. They chose a subject, for example, "Meiosis" in the animal kingdom. An initial questionnaire, which was short and sweet, was hammered out for the purpose of completing the handful of introductory technical exercises which the OPE gave to all student newcomers.

A second questionnaire, far more complete, was made up afterwards.

These questionnaires were submitted to various groups of undergraduate majors, and were also shown to a large part of the biology teaching staff to get their reaction.

The six biologists had had no previous experience in the fields of computer-assisted instruction, computer techniques or data processing.

It is rather different to calculate exactly how long it took to put together the questionnaires (getting the wording of the questions, the various answers that could be expected, and the corresponding explanatory comments) but certainly several hundred hours were involved.

Next, it was necessary for the biologists to play at least some part in actually making the questionnaires (punching the cards, recording on the diskpack memory, etc...). They were readily trained in computer practices with the active co-operation of the entire OPE staff.

Working out and physically preparing the questionnaires was done in work shifts which were added on to normal teaching and research schedules.

B. The subject matter

The very character of biology, its development, and its teaching needs raise special problems, some of which have not yet been adequately solved.

In biology there are very few assertions which are true universally. Each so-called "general" rule usually carried with it restrictive clauses varying from one group or another, sometimes from one species to another or even from one individual to another. Peculiarities, anomalies, pathological cases tend to reduce even more the scope of a general law and make it all the more difficult to write questions and explanations which must be terse if they are to be used in the computer.

It is likewise necessary to plan for some student answers which deal with such and such a specific case, not the most typical case.

A single concept, fact or object in biology can be described in two or several ways (for example: synapsis and conjugation of chromosomes). These various names coexist and in fact are used, so that students who have taken courses from a number of different professors have had to learn noticeably different vocabularies for the same subject.

A single word can have various meanings, especially both a "broad meaning" and an "exact meaning". For example: Egg. Sometimes one term refers to objects or facts which are entirely different, depending on what group of animals or plants is being studied. (For example: tetrad). Furthermore, two names which one biologist considers to be equivalent are thought of by another biologist to be distinct, even if only slightly. Finally, a term may have undergone what linguists call a "drift in meaning" since it was first coined or used, as a result of the development of knowledge and ideas.

In virtually all branches of biology, drawings, graphs or photographic materials must be used. Without them, a student may be called upon to exercise his imagination and his ability to do abstract and conceptual thinking. But most of the time, doing without them results in description loaded down with tedious circumlocutions. Biology teachers claim, quite rightly, that in biology a good sketch is generally preferable to a long explanation.

It was possible to handle meiosis in the questionnaires without using illustrations, although analysing the processes of crossing-over, for example, which was considered briefly, would have raised dire problems.

C. <u>The main features of the questionnaires</u>

The questionnaires developed are designed to allow the undergraduates to engage in "self-examination" after they took courses at the Faculté des Sciences (lecture courses, discussion sections, classroom practice). The OPE session is optional. No marks or evaluations of any sort is given students by their usual teachers or by other parties.

The first questionnaire, labelled by the symbol <u>K 18</u>,("Introduction to Meiosis") has a simple form - it is made up of 12 questions in normal sequence, without any jumping to side tracks. The purpose is to emphasise some general concepts, without going into detail on the mechanisms involved. It should enable the student to become aware of whether he has understood the meaning in biology of meiosis, whether he can locate it in a living organism, whether he knows the starting and finishing points, and so on. It also makes it possible to go into more detail on certain terms and notions. K 18 ends by announcing a more detailed questionnaire.

The second questionnaire, carrying the number K 68 ("New programme on Meiosis"), is in fact made up of two sub-questionnaires - K 68 proper, and K 19 - which must be automatically hooked together. It comprises a total of 31 questions, 27 of which are in normal sequence and 4 jumping on to sidetracks.

It is concerned with exactly how meiosis occurs. "Reduction division" is dealt with, naturally, in a large number of questions. The essential notions - "pairing", "homologous chromosomes", "chromatic reduction", "chiasma", "crossing-over", "autosomes", "heterochronosomes", etc. - emerge during the process, either from the wording of the questions or from the explanations.

It ends with the notion of returning to the diploid state as a result of fecundation, and with the importance of "stirring up the gene pool".

A final survey should make it possible to know, in part, the students' opinion of the questionnaire and to receive their suggestions for future programmes.

The first questionnaire, K 18, being simple in design and construction, is acceptable for an "introductory" session. It is no longer appropriate for other questionnaires, which are more complete and have higher ambitions.

The second questionnaire, K 68, with its two parts, is too long. To completely debug such a programme takes a long time, and involves drudgery, since each modification often necessitates other changes and so on.

K 68 should have skipped over the problems which were simple or easy to understand, merely referring them off to various sidetracks, and should have concentrated basically on a thorough study of a limited number of questions.

Generally speaking, the questionnaires were designed to review all the important notions, whether they were simple or complex. This plan has had its day.

There are too many questions such as "What do you call ...?", despite an attempt to diversify nomenclature. Although questions of this type need not be excluded, especially when they concern difficult or new terms, it is usually best to have the student himself explain how facts work or occur. Nevertheless, the fact that an answer must not be longer than 58 characters imposes a limit in this direction. This problem will have to be studied once again.

On the whole the questionnaires perhaps do not utilise fully all the present possibilities of the machine. In this respect, it should be mentioned that in some future programme, the student may be called upon to make computations, and it will be easy to use the computer for this purpose.

The multiple-choice question format was not used, with just two exceptions.

In nearly all cases, the student himself has to write in the key word or words, and therefore has to find them first in his memory or as the result of a chain of reasoning.

The attempt to think and to actually build words, which to a certain extent is comparable to true re-creation, seems to be of fundamental pedagogical importance, even if the student is not entirely aware of it at the time.

Each student must have a minimal vocabulary, without which he cannot study biology. For example, in K 18, question 05 (naming the cells in which meiosis can be observed) normally calls for the answer: "germinal" or "germinative cells". The answers, "sexual cells", "reproductive cells" or "gametes" are unacceptable (they are expected in the answer-block). A certain amount of strictness is required. For question 15 in K 18 (naming the male cell at the end of meiosis), the answer "sperm" instead of "spermatozoid" is refused and an explanatory comment is given.

The questionnaires are limited to the most important and general concepts and facts and to those which prove toughest for the students to understand.

Experience in teaching often shows that thorough knowledge of a complex nomenclature is not necessarily connected to a sound understanding of the mechanisms involved. The computer should not be used primarily for the purpose of aiding students to memorise long lists of words (even if that cannot be totally avoided). In particular, in the two parts of K 68, some ten questions deal with prophase I. The usual nomenclature for the successive stages of this phase are neither mentioned in the questions and explanations, nor called for from the student (with the single exception of diacinesis). The characteristics and basic facts of this prophase I and what distinguishes it from a homeotypical prophase are emphasised.

The questions vary in format and character. Either the name of some fact or object, or a terse description of a phenomenon is asked for. A few problems requiring rigorous thinking are raised, and sometimes what may be called "traps" are set.

The questionnaires are adjusted - albeit inadequately, it is true - to the spread of levels of knowledge and understanding which can be expected among students.

The commentary which follows a mistaken answer sometimes asks the question again in a slightly different form, even adding new explanations (cf., gametogenesis).

D. Results and student response

In all, more than one hundred undergraduates participated in answering the first questionnaire (K 18). About a third of them were able to return to do the second one (K 68 + K 19). Various adverse circumstances - in particular, the final examination period - prevented the others from coming back, although they wished to do so.

A session for each student lasts usually from 30 to 45 minutes. Those few students who remained for a full hour began to feel tired.

It is worth noting that part of the reason the students showed such keen interest in this experiment is that all technical and pedagogical novelties are appealing.

Although the students felt constrained by the physical difficulties of handling the control panel, they rapidly came to feel at home.

The experiment showed that the student should feel free and unobserved while he is carrying out his "self-examination", and the staff should intervene only when called upon. This is especially reasonable in that the computer gives the student the correct answer after two mistaken answers.

At the end of a session, the computer is able to supply a statistical inventory containing the various types of answers which were given to each question, the average time the student took to answer, and a list of all answers which were not anticipated.

In the present state of development, the most interesting data came from personal conversations with the students after the various sessions. Useful albeit fragmentary information has already been obtained in this way.

The students were duly informed that this work was experimental in nature, that they were considered to be fellow researchers rather than pupils, and that their reactions were going to make it possible to improve the questionnaires, develop others with different patterns, and help the teaching staff to define its most effective role.

The students themselves expressed the sense that they were "relaxed" around the machine.

As a rough guess it would seem that a student who is not sure of an answer is more willing to say so than he would be to a professor.

Students who feel free to express themselves, and are required to seek their answers actively, seem likely to learn more readily. The details of this process have not yet been demonstrated and understood.

Furthermore, it can be assumed that if the student forms the habit, by this method, of answering more readily, he will apply it in other kinds of examinations and will have increased self-confidence.

From the very outset, students are overwhelmed by the need to give accurate answers. In traditional examinations, they can beat around the bush, little by little coming closer to the solution, and finally managing to make themselves understood with the aid of a "you see what I mean" or two. That is not the case here.

The undergraduate biology majors find the need to be rigorous so new and baffling that at first they do not really know whether they should be delighted or dismayed by it. After a while, they generally end up favourably inclined on this point.

There are two contrary perils which must be steered away from:

- first, personification of the computer, which has the tendency of ascribing human behaviour and responses to it.
- second, mechanical coldness under the pretext of being "neutral", which in the long run would be disagreeable.

The students seemed to be satisfied with the balance finally reached in the questionnaires.

An OPE session is useless and not to be recommended for students who have not studied "Meiosis". Students who studied this topic specially in order to prepare for a session did not benefit as much as they expected to. It happens that the questionnaires were not designed for that level of knowledge, despite the attempt to give them a wide scope. One of the tasks in the future will be to add more variety to their structure to make them appropriate for a wider audience.

The session is clearly beneficial, above all, for those who have studied Meiosis the same amount as they have other parts of a regular course, and who as a result are still in the dark or are unsure of certain points. In the last analysis, that describes the majority of the students who came to the OPE.

The students are very interested in the experiment and are generally convinced of the effectiveness and future outlook of the method. They all hope it will be expanded widely.

Some students seemed troubled by the prospect of a mechanical, automated universe which looks like it would have to eliminate human thinking and initiative little by little. At any rate, such preoccupations can not be overlooked.

Some of the questions were not formulated in a satisfactory manner. As a result, the questionnaires were reworked whenever it seemed necessary.

After an inaccurate answer, instead of giving out an all-purpose formula such as "Think and answer once again", the computer ought to ask the question again in a different form, if need be with new information.

This observation is probably one of the most pertinent and constructive ones made. From the outset, this process was used occasionally, but not often enough. Since then, the questionnaires have been changed appreciably in this direction, at least for some questions. In the future, this problem will attract the attention it deserves.

Some questions appear to be just about useless, when their answers are too easy or too obvious. Although this observation is justified, it was not possible to change the questionnaires accordingly, since the whole concept of the experiment was involved. Future programmes will be based on entirely different patterns.

Students often wish to engage in a dialogue with the computer. More particularly, they would like to be able to ask the machine questions, request definitions or even the complete explanation for a

concept or a part of the course which they did not understand clearly.

At the present time, requesting a definition can be done as a result of the "system for automatic information" being built.

Later on, it will be possible for the student to ask that a question be restated, to request further details or fresh information in order to locate a problem better, or even to reject the question he has been asked, at least for a while, and to ask another instead.

On the other hand, the present conception of the method allows no place for having the computer expound part of the course, and any such alteration would raise all sorts of theoretical and practical difficulties that require cautious attention.

In summary, and taking note of the reservations which have been mentioned, it can be said that the students are satisfied with the method and the questionnaires, and they hope there will be more of them.

The most favourable response may have been that voiced by students who, on leaving the OPE, declared: "Now I know what part of the course I have to review".

E. Teaching staff's opinion

1. Reservations expressed

Every new technique unavoidably encounters scepticism and hesitation at the outset, or at least forces people to wonder about the timeliness and the advantages of possibly upsetting fixed habits.

Such reactions are to be expected, and they can be useful and stimulating if they lead to more careful work, deeper thinking and more convincing results.

It so happens that very little scepticism was encountered on the whole from fellow biologists or colleagues in the various academic departments at any level of the faculty.

The main reservations expressed were:

- Refusal of any attempt to substitute "computer-assisted instruction" for the usual forms for handing down and checking on knowledge.
- Confusion in the face of the high cost of financial, material and intellectual investment which applying and expanding the method depend on, and doubt as to its real usefulness.
- Hostility, based on principles, to any automatic device coming between teachers and students, and threatening to change or cause a breakdown in human relationships.

2. Enthusiasm

Generally speaking, fuller communication tends to reduce considerably nearly all scepticism.

In particular, the resistance weakens as soon as opponents understand the notion of a "computer", with the traits and possibilities which distinguish it from a mere limited, linear mechanism, and as soon as they grasp the precise nature and limitations of "self-examination" using a computer.

On the whole, their scepticism, reservations and anxiety turned into well-intentioned interest, and sometimes into warm approval, or even into true enthusiasm, after they had had direct contact with the computer and the method and had actually used the questionnaire.

Nevertheless, the important and even serious problems which have been mentioned did not disappear. Solution to them will not be found until it is demonstrated clearly that the method has specific merit and is irreplaceable, and until everyone agrees that there is a true need for it.

It is clear that the first assessment of the reactions of the biology teaching staff is positive and clearly encouraging. Their numerous observations and suggestions are highly valuable in view of future plans to continue and improve this project.

4. AN EXPERIMENT IN USING A COMPUTER TO TEACH ENGLISH LINGUISTICS TO UNDERGRADUATES (RULES; OPERATIONS; METALANGUAGE). CHARLES V ENGLISH INSTITUTE - STUDENT COMPUTER USE AT THE HALLE-AUX-VINS CAMPUS

A. Problems involved

When the Charles V English Institute was founded for the purpose of carrying out interdisciplinary studies, it became possible to initiate a good number of pedagogical experiments designed to modernise the teaching methods at the Faculté des Lettres (School of Humanities) based traditionally on literature, by using modern linguistics and applied linguistics as much as possible, by emphasising the spoken language, and by increasing interaction with the social sciences, such as psychology and sociology, and the exact sciences, such as mathematics, logic and data processing.

After contact was made with the OPE at the Faculté des Sciences, they formed a team under the direction of Mr. Culioli, Professor of Linguistics at Charles V. The prime mover in this group is Mrs De Vos, Assistant Professor of English Linguistics, and it includes four students at the Master's degree level and one or two psychologists.

An experiment in programmed instruction should serve as a stepping stone to creating an Institute for Research in Language Teaching (I.R.E.L.).

The experiment introduces English-language linguistics to freshmen and sophomores. A battery of seven questionnaires are planned for the year. The students enrolled in the experimental groups, who are all volunteers, will alternate OPE sessions with normal classroom work. A control group studying the same syllabus by traditional methods has been set up in order to make it easier to evaluate the outcome of the

test groups. At the end of the year, it will be possible to compare the level reached by the two types of instruction, by setting up an examination on punch cards.

It is important to explain why linguistics, i.e., a subject containing theory, was chosen, rather than language learning itself. It would have been possible to set up a course in standard English for adult beginners. In point of fact, the Charles V English Institute is wrestling with the problem of adult education, among other things, and the experiment would be worth trying. But it looks like computer-based instruction in its present form is more specially appropriate to scientific disciplines. It requires that the material to be taught be divided up logically into minimal units and that a rigorous gradient be defined. That is relatively easy to do, for example, when dealing with the rudiments of algebra, but this procedure is hard for the so-called literary disciplines or for modern languages. In particular, the range of possible answers, right or wrong, is much broader, and it is hard to anticipate what they will be. This weakness is compensated for by Skinner-like programmes in which the subject matter is chopped up as much as possible in order to literally "impose" the right answer on the student, which results in questions which are too easy and in continual repetition, hardly a stream-lined system for university-level teaching. Furthermore, it does not adhere to the individual's rate of progress and quickly bores the quick students. A computer makes for much greater flexibility, as a result of the possibility of jumping to side tracks and varying the explanatory comments as a function of the answers received.

For modern languages, in addition to this problem there is another: the learning process must be largely oral. Audio-visual methods and language laboratories, which are being used more and more widely, are designed for this purpose. Nevertheless, techniques alone do not work miracles in this field; course content and hence instructional programming count.

In computer-based instructional systems such as that used at the OPE, the dialogue with the machine is done only in written form. It would therefore be a waste to use this complicated and costly means to teach a foreign language, as well as a serious error in teaching because it would contradict the audio-visual methods. Adding a screen and a tape-recorder to each terminal would improve the system appreciably. One aspect of aural-oral teaching with visual support would be achieved, in that students would hear, and in addition the screen would make it possible to use slides. But the basic problem remains of the sounds the students produce, and this belongs to the realm of utopia, since no computer is yet able to decode the human voice. Let us hope that that is accomplished some day. Meanwhile, in the near future it will be possible to give an entirely automated so-called "comprehension" examination, in which students will listen to a text in a listening room and then will take a written test designed to check their understanding of the text. It would be an improvement to have the second part of the test handled by machine, with each kind of answer calling forth an appropriate explanation. But these are long-term plans.

For these reasons, bearing in mind the limitations of the system, and wishing to put to maximum use the experience garnered from three

years' scientific practice at the OPE, we were compelled to choose a subject matter requiring the teaching of theory.

Teaching is the key word here, since our purpose is not to turn out examinations for testing knowledge learned elsewhere (in lecture courses or discussion sections), but to develop a full two-year programme for introducing English linguistics to undergraduates.

B. The programme

Starting with a simple sentence, "John likes milk", the simple sentence will be decomposed into a noun group and a verb group.

first questionnaire:

- breaking the sentence down into noun group and verb group.
- how the verb group works: this casts light on the key part played by the auxiliary verb.

second questionnaire:

- possible combinations between simple or modal auxiliaries.
- transformations of the simple sentence.

third questionnaire:

- the auxiliary used anaphorically with the verb group.
- systematic study of all repetitions and tags.

fourth questionnaire:

- defining grammatical tense, aspect, voice and mood.
- their different combinations and incompatibilities.

fifth questionnaire:

- contrast between "linguistic" and "extra-linguistic".
- tense and time sense.
- grammatical and extra-linguistic aspect.

sixth questionnaire:

- the noun group.
- the various factors determining the noun.
- combining determinant classes.

seventh questionnaire:

- consistency between determinants and nouns.
- singular, plural and collective nouns.

C. What was accomplished

Preparing and debugging questionnaires is a lengthy and hard job, even when done in committees of five. Once the practical weaknesses have been patched up, they must be tested on student guinea pigs. At that point the basic bugs show up. Answers which were not expected, once classified in ARF and handed back by the machine, offer interesting guideposts. Some right unexpected answers must be added to the answer block, some wrong answers deserve a special commentary or even a jumping sidetrack, some explanations appear inadequate in view of the high percentage of wrong answers. In the end, nearly everything has to be gone over. In fact, there are as many corrections as testers. For this reason, it is vital to know when to stop trying to make improvements. This is the hub of the problem. Once a questionnaire is fed into the machine, it has a fixed form, and it does not lend itself the way live teaching does to improvised correcting, fresh doubts and inflections. What it gains in logical rigor it looses in flexibility. Hence the subject matter taught must not be subject to revision at least during the time it takes to make the programme worthwhile. If a questionnaire falls out of date too quickly, a considerable amount of effort is lost, to say nothing of material costs. This is a real danger in linguistics, a fast-moving science in rapid expansion. One is therefore forced either to be willing to use questionnaires whose contents are less than fully satisfying, or to be bound by simple and well established notions to avoid being challenged by the time the programme is finished. Since questionnaires are programmed by men and not by machines, it is difficult to cut down on the time it takes to complete the project. Hence it is vital to arrange to make the programme as profitable as can be.

Another special difficulty which linguistics raises is that statements often turn out to be longwinded and verbose in order to be clear. The result is that the student spends much more of his time being passive (reading the text) than active (thinking and answering). In addition, the limits on the number of characters in each block (caused by the modest capacity of the central store) sometimes result in dummy-questions, which tends to make the student even less active since he is not asked to think but only to type out "yes". Finally, the requirement of having each session last about three-quarters of an hour results in cutting up the questionnaire clumsily, since each unit has to form an independent set. It would be preferable for each student to be able to start out a questionnaire at the point he left off at the previous session, and thereby to be able to progress in the programme at his own speed. This would require that the machine be able to remember from one session to the next the number of the last question which each student was asked, so that it could send him on automatically to the next question. Since the questionnaires are linked up to one another in logical sequence, one student might get through the programme in six weeks, while another would take twelve weeks.

These are manageable problems. Initial tests on a mixed group of student guinea pigs proved that the system is viable, at any rate. Ten of the fifteen students tested declared that they learned something. Only two found the questionnaire too difficult. On the whole, excluding some small technical problems, there were no serious problems in adapting the subject to the machine. Even students who did not know how to use a regular typewriter learned very quickly how to handle the keyboard. The fast ones took less than an hour, the slowest two and

a half hours. Curiously enough, the first question evoked a large number of mistakes even though it was very easy. This is due to the emotional state of the students at the outset. The most important problem seemed to us to be that of making students understand that this was a teaching method, not an examination. Some students are content to give the right answer and do not bother to read the commentary attentively and do not pause to think. They are so used to examinations that they seek to perform rather than learn. Such students require a new mental framework, and that is a problem that goes far beyond the scope of a computer-based instructional programme.

Our initial results are thus encouraging, even though the population sample tested and the duration of the experiment are too limited to enable us to judge the pedagogical value of the programme. It is impossible, at such an experimental stage of development, to handle large numbers of people. At any rate, the results may be distorted by the fact that the student guinea pigs were volunteers, more highly motivated than the average. This problem would not crop up if we worked on all the beginning undergraduates, and that is our long-range goal.

The outlook is very good for dealing with other groups besides beginning undergraduates. This kind of instruction seems particularly well adapted to continually re-educating high school teachers, because it is so flexible, especially the hours at which it can be scheduled. Teachers can be on both sides of the fence at once since they can bring their knowledge up to date and at the same time be introduced to programming (in both the sense of an instructional progression, and as the process of preparing material for the computer). Candidates for various national competitive examinations ought to take an interest in computer-based instruction. As the programme is planned, it dovetails perfectly with the syllabus of the Single Recruiting Standard programme (MUR) devised by the Faculty of the Charles V English Institute. Some people in this programme will be able to benefit from the OPE this year.

In addition, there is another sector which we would like to see develop into users of the OPE, namely, the automatic documentation sector. Storing some fundamental definitions in the machine would certainly help to avoid repetitions and backtracking in the questionnaires, since it would enable the student to call for information to check the meaning of a word previously used, a situation which may occur rather often in linguistics. Once again, the limitation in the number of characters available causes trouble, but the search for concise definitions turns out to be an excellent mental exercise.

IV. SUMMARY AND CONCLUSIONS

A. Make-up of the present research team

- The team "nucleus", which has to provide a certain stability, is made up of 2 professors, 5 computer experts, 1 researcher and 2 psychologists (i.e. 10 people in all, 6 of whom have doctorates).

- The staff of professors connected to the OPE includes 6 mathematicians, 4 physicists, 7 biologists and 1 professor of English.

- The staff of secondary school teachers is made up of 4 teachers currently assigned to the OPE half-time.

- The temporary staff (paid for out of the budget mentioned above) includes some twenty people doing various tasks: writing, typing, testing, handling statistics.

B. Defining the problem

The first step we set out to take was to make the student aware of how much he knew and to draw his attention to the basic concepts, fundamental definitions and important theorems. Purposely trying to limit our scope, we called this "self-examination".

This self-examination is achieved by means of questionnaires given to each student by a teletype with special characters. The questionnaire is designed to:

- check on knowledge of certain notions

- supply extra information

- make a synthesis of different notions possible

- offer exercises for applying the material.

After that, in the case of the course in English linguistics, the student who has received no previous instruction in the area is introduced to the concepts themselves.

We put the following restraints on our programme:

- the answers must be open and analysed (such that multiple-choice questions are practically outlawed).

- the patterns for branching should be as varied as possible.

- the computer should be able to be used at the same time as a tool for computations.

- information obtained during a conversation between the machine and the student should be stored and available for subsequent use (in particular, to study and define instructional strategy).

We expect the following results from this work:

- students immediately interested
- feedback on the course
- information on learning models (description of a student's state, study of errors, etc...)
- improving and designing more individualised instructional strategies
- defining what characteristics are necessary for the hardware and software to be used in different types of computer-based instructional programmes.

C. What the "computer" team has accomplished

With an IBM 360-30 computer having a small central memory (16K eight-bit bytes) supplied with a diskpack storage capacity of 7.5 million characters, we had the intention of managing 20 typewriters.

It was necessary to:

1. Modify the basic operating system by adding on some Disk Operating System macros, write all the input-output programmes and change the supervisor's FETCH macro (a small dictionary of the phrases used is stored in the central memory, to avoid long and unnecessary disc readings, while the non-permanent programmes are called for in a relay area).

2. Invent an initial author language composed of related Question-Answer blocks with possibilities for branching (without loops).

3. Carry out an analysis of the verbal answers by looking for one or several key words (or their synonyms). The code is not the same depending on whether the order of the key words is important and whether the word separators are the "blank space" character alone (the case for some formulae) or one of the "space", "period", "comma" or "apostrophe" characters.

4. Carry out a formula analysis taking into account parentheses, reductions to the same denominator, simplifications, and uncommutable symbols so that each equivalent formula is rewritten in the same conventional form.

5. Design different programmes making it possible

- to call for information and to list the calls
- to notify the user of his mistakes in syntax
- to input a questionnaire from the consoles
- to post the operating programme for a questionnaire
- to discover in which column of the punch card there is an error in syntax
- to enable the student to add comments as he chooses and to indicate how sure he is of his answer

- to print the listing of a questionnaire on the terminal
- to supply statistical results (on errors, unexpected answers, answer time, degree of certainty).

6. Invent a more complicated author language which allows for a more flexible connection between question and answer blocks in order

- to give rise to a questionnaire by connecting these blocks
- to authorise adding specific commentaries between two blocks
- to control the flip-flop switches indicating the student's route
- to feed the counters which measure each student's reactions
- to decide on branching based on the previous counters, whereas in the original author language, branching is determined solely by the last answer which the student gives.

7. Design two versions of a conversational programming language derived from FORTRAN and allowing the 20 control consoles to use the computer as a tool for making calculations (during the examination period or at other times). The second version (Symple) makes it possible to have partially correct programmes, conditional or unconditional jumps and panel writing.

In addition to its normal work load, the staff of computer specialists has helped several research workers and students to use the computer during off-peak hours (at night or during university holidays).

D. What the teaching team has accomplished

- The mathematicians applied the "Symple" conversational language to the task of introducing numerical calculus to beginning undergraduates by means of a computer (two full days per week, that is, 8,000 student-hours).
- The physicists drew up some forty questionnaires for undergraduate majors in the areas of Electricity, Electro-magnetism, Thermodynamics and Statistics. These questionnaires were taken advantage of to a greater or lesser extent by some fifty students (around 1,200 student-hours).
- The biologists designed 3 questionnaires in biology, used by about 100 students (200 student-hours).
- The English department faculty drew up 3 courses used by some thirty students (100 student-hours).
- Various odd jobs done for secondary school teaching (computations or questionnaires) cover about 200 pupil-hours.

In introducing students to data processing, they were first shown how to write small computation programmes requiring a few logical decisions (second degree equations, prime numbers, and so forth). Then they learned how to design less trivial programmes revealing the

differences between calculations by hand and with the machine (determinants, inverted matrices, roots of algebraic or transcendent equations ...). Finally they encountered some logical manipulations such as the different methods for sorting a file.

The self-examinations in physics and biology and the linguistics course raised major difficulties for the professors concerned. Some of these were solved with the help of the staff researching teaching problems, while the team of computer experts strove to supply them with the different techniques which gradually they found use for as work progressed.

In physics the faculty first divided up a standard text book in Electricity into some thirty units, each of which was to be the basis of a questionnaire. Each questionnaire was handled by two professors who worked out an overall plan; a group discussion led to a first draft which was then criticised by the full staff; the questionnaire was then shown to students, who in turn suggested modifications. This procedure did not change very much and was adopted by the biologists and the linguists, except that the physicists also attempted to involve experienced students in designing the questionnaires. It is hence easy to see why 250 to 300 hours of work are required to prepare a single questionnaire. The physicists' work had to be redone following two consecutive reforms of French higher education. A goodly number of the questionnaires worked out in recent years have had to be cast aside because they no longer match the subject matter being taught or because their wording was too close to that of a written text book while we have managed to set down a few basic points for a pedagogical strategy in this field.

It is our judgment that the first task is to define the <u>general purposes</u>: what are the exact purposes of teaching, the goals expected from analysing the outcome, the building which will occur as a result of their goals. Next, a <u>writing technique</u> is set up: writing a first draft (to cast light on the size of the project, its organisation, the data), analysing the subject (what concepts are to be introduced, what concepts is it assumed the student knows, what forms will the questions and reasoning take, what type of errors are involved...), establishing a detailed diagram showing the notions and their connections, writing a refined version, formulating a tableau showing the key juncture points of the diagram in order to prepare the way for subsequent research. Finally, within the framework of any given strategy, <u>certain construction rules</u> are chosen: limiting the number of notions, making it possible to analyse one notion which appears in different questions on different questionnaires, having possible commentaries for correct answers take the form of "Yes, indeed...", having commentaries for wrong answers offer help enabling the student to answer once again, having as few commentaries for unexpected answers as possible because they cause too many problems, limiting notation and repetitions.

The biologists not including sketches or diagrams in their questionnaires now have some experience in the field of analysing a "rather free" sentence which answers a <u>very accurate</u> question (naming a fact or an object, describing a phenomenon briefly) aimed at the level of knowledge and understanding which the students can be expected to have. One problem which seems to have been solved comes from the fact that the different authors do not all use the same terminology,

that a single concept can have several names and that one word can have several meanings (for example, the word "egg").

The English department staff, in undertaking to design a true course, is striving to avoid a Skinnerian plan which would "impose" the right answer, to reduce the verbose appearance of a text in which the important points are far from clear, and to keep the form from becoming too fixed.

E. Nature of research work on teaching

The work carried out is made up of three major parts.

1. Nature of the teacher-student dialogue

First of all, seeking out and debugging those operating tools which are useful to the teacher:

- formula analysis
- analysing a sentence by key words, with the logical keys AND, OR, EXCEPT
- possibility of conditional branching
- analysing some spelling errors
- indicating that an answer is incomplete
- tracing curves on a rapid printer
- asking how sure the student is of his answer
- counter the number of errors
- measuring how much time passes between giving the question and obtaining an answer.

Next, seeking and debugging those operating tools which are useful to the student:

- total or partially erasing what he has written
- calling for a dictionary
- possibility of offering comments at the end of a questionnaire
- calling for the possibilities of numerical computation
- possibility of rejecting certain backspacing that he considers useless

2. Nature of teaching strategy

- dividing the subject matter into smaller units
- introducing the subject matter
- decision to introduce backspacing
- decision to have branching
- deciding a priori what errors are possible

- deciding how difficult or important a concept is
- deciding on the purposes of a questionnaire

3. Nature of a learning model

Here is the first breakdown of a study of errors which was done on one specific questionnaire:

- errors due to the way the question was formulated: 11 per cent
- typing errors: 18 per cent
- errors which can be attributed to the students' not knowing laws or concepts: 22 per cent
- errors due to misuse of laws: 44 per cent
- no answer given: 5 per cent

This initial study is necessary to evaluate how much a student knows, which in some cases is measured in numbers whose meaning needs to be made clear: the number of mistakes, the time the student takes to answer, how sure the student is of his answer, retention time.

This kind of study is just beginning: it is still too soon to come to any scientific conclusion about how valuable any one introductory method or how effective such and such a strategy may be.

F. Conclusion

1. The cost/efficiency ratio

One way to calculate costs reveals the following price tag per student-hour:

$$\frac{\text{3,300,000 Frs (Total cost)}}{\text{10,000 student-hours}} = \text{330 Frs/student-hour (equivalent to about \$60)}$$

$$\frac{\text{600,000 Frs (cost of renting the computer)}}{\text{20 terminals x 3,000 hours per year}} = \text{10 Frs/student-hour (about \$2)}$$

The first cost figure includes the entire research and debugging part, and was raised even more by the fact that many of the students who participated in the programme had not reached the desired level. The second figure is much closer to the actual price of running such a programme, but it should be at least doubled to take into account paying personnel salaries. It should be remembered that the University of Illinois, which is the institution with the vastest experience in this field (with more than 100,000 student-hours in the last ten years) estimates that it costs 0.2 Frs ($0.04) per student-hour for a large computer, equipped with 4,000 terminals, which is prepared with the fourth version of the PLATO project.

How effective the programme is cannot be discerned from the student comments which the computer gathered or by a psychologist, since all the students who participate are volunteers.

Nevertheless, the fact that they return without being paid (for they received no compensation of any sort) and that they continue to do so after the novelty has warn off, shows that they benefit from the experience. The casual atmosphere of discussions with the faculty is something new for them. Some of the students feel less anxiety-ridden than they do when facing a human examiner. Many of them are pleased with the accuracy and rigor which they are forced to accept.

Our original purpose was to improve the way examinations are given, something hard to make effective in mass education. By a combination of the computer and discussions with the teachers, we think we have managed to succeed.

2. <u>The choice of subject matter</u>

We note that the cost is stationary for the physicists, but decreases rapidly for the biologists.

The fact of the matter is that the physics course involves about one hundred students, while it was designed, before the 1967 educational reforms, for the 2,400 students enrolled in the undergraduate Electricity course whose four professors had decided to launch the experiment.

On the other hand, the biology questionnaires are prepared for the thousands of students beginning their general science and pre-med programme (P.C.E.M.) as well as for hundreds majoring in chemistry and biology (CB-BG). For this reason, the Biology Department running these undergraduate programmes voted unanimously to co-operate with this experiment.

Furthermore, in the early groping stages the physicists made the mistake of preparing too many questionnaires of low quality. The biologists and English linguistics were able to benefit from the improvements in design techniques made after early errors, and thus were able to write questionnaires and courses of good quality right away.

The biology questionnaires have already been taken by several hundred students, and lend themselves well to statistical analysis.

It thus appears that the computer is best used in mass education, for both instructional assistance and research on teaching methods.

One of the difficulties which the physicists encountered is also related to the comparatively high intellectual level in the field of statistical thermodynamics. However, this choice proved to be a good point to begin, since the methods developed can now be applied readily to elementary undergraduate courses.

One of the goals we are presently pursuing is studying what help a computer can be in various kinds of teaching, and in particular we are investigating what conversation languages may be sufficiently universal.

It therefore seems useful for us to expand certain experiments in the field of mathematics, geography, language learning and spelling. The co-operation of linguistics is more and more necessary.

3. The choice of hardware

The least expensive terminal is a typewriter. They are noisy but they have the positive feature of leaving the student with a record he can hold on to. Using a keyboard is not a serious issue.

While we wish to avoid the out-and-out mechanisation implied in using advanced terminals (cathode screens with a light pen or slabs which analyse handwriting), we would like to use some inexpensive apparatus, such as viewers or tape recorders which can prove very handy for delivering various messages.

We are not trying to use the computer to "turn pages" but to make forward strides in applying new instructional strategies such as prediction simulation or other experiments.

In the same fashion, a curve plotter or a cathode screen would be very useful for plotting diagrams and solving differential equations step by step, showing students how important each parameter is.

The main reasons students are limited in using the computer at the present time are:

- Storage capacity too small to carry out simultaneously the various operations (questionnaires, input, listing, statistics, correcting, tests, etc.)
- Insufficient storage of valid questionnaires
- Insufficient number of junior faculty members to handle the students
- Too rigid a schedule for access time.

In order to increase the schedule of computer use, including at night and during holidays, we consider it important to be able to work freely by having a few terminals located elsewhere than in the OPE's offices, perhaps in a high school where the staff could develop the pupils' common sense and ability to reason with the help of a computer, just as has already been done in many schools in the United States.

4. Improvements in software

Several research efforts are under way in France to determine the right characteristics for author and student languages. We have made the observation that these languages should contain certain qualities which the teaching staff has felt is needed. We shall list the following operating possibilities which should be developed:

- For the student:

  - Asking for information, documentation, and data
  - Asking for help or added explanations
  - Asking for commentary or concrete examples
  - Asking to back space
  - Calling upon the teacher directly
  - Possibility of introducing his own comments
  - Possibility of disagreeing with the machine's comments
  - Possibility of indicating that a common typing mistake (capital-small letters) has been made
  - Asking for an outline which explains the purpose of a questionnaire
  - Asking to speed up or slow down the rate at which concepts are covered.

- For the professor:

  - Easy and ready way to input a new version of the questionnaire
  - Possibility of asking the student a second time the important questions which he failed to answer
  - Having the computer mark the words the student does not know
  - Recognising a word by its outline or its substance
  - Eliminating useless words from the analysis of a sentence
  - Acceptable latitude for numerical answers
  - Rough plotting of a curve on a typewriter
  - Breakdown of reading, thinking and typing time
  - Creating characters for a visual terminal.

5. Research on teaching

The computer is not only a tool which makes it possible to improve standard teaching and to introduce new pedagogical methods such as case studies, prediction and simulation, it should also be the tool used to measure the student's progress, deduce the characteristics of a learning model, define the characteristics of a teaching strategy, judge what influence that strategy has on the student, thereby refine the learning model, and step by step improve the strategy which is to be applied to each student.

Such a task can only be accomplished by means of close co-operation among psychologists, linguists, logicians, statisticians, electronics experts and specialists in each of the subjects taught. Hence it is necessary for us to train researchers who are educated in more than one discipline.

V. PUBLICATIONS

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